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Understanding, assessing and modelling sustainable eating behaviours

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Abstract

Sustainable diets are aimed at promoting and supporting psycho-physical health and social well-being for actual and future generations by means of accessible, safe, healthy, environmental friendly, affordable, fair and acceptable food. Shifting dietary habits towards healthy and sustainable dietary patterns has been proved to represent a drive of change for more sustainable food systems, besides exerting beneficial effects on health outcomes and contributing to the mitigation of the climate change scenario. To drive this behavioural transition, tailored solutions need to be developed by applying strategies at multi-level involving different sectors within the food system and addressing the heterogeneity of social, demographic and economic background of the population. The complexity of dietary behaviours and the influence of a wide range of intrinsic and extrinsic determinants on dietary choices require a multidisciplinary approach addressing sensory, psychosocial, cognitive and environmental stimuli. Understanding consumer behaviour is crucial for developing strategies and interventions to foster the transition towards more sustainable diets at both individual and population level. In this framework, the application of psycho-social models to understand and predict sustainable eating behaviours is a valuable technique to design effective interventions.

Based on these considerations, this Doctoral Thesis aims at providing recommendations for the development of effective intervention strategies addressed to improve the sustainability of dietary behaviours in childhood and adulthood. To pursue this objective, the first part of the thesis addressed the role of personal, social and environmental factors in explaining and predicting the adoption of a sustainable diet in the adult population, by applying a social-cognitive theoretical framework. The second part was focused on assessing the eating behaviour of primary school children, through the analysis of the sustainability outcomes of their school lunch plate waste in terms of nutritional, environmental and economic losses.

First, a systematic review was carried out to identify the main drivers and barriers towards sustainable diets in adults by applying three psycho-social theories, i.e. the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour (TPB), and the Social Cognitive Theory (SCT). The analysis of the reviewed studies showed a multitude of significant predictors of intention and behaviour. The most recurrent were

attitude for intention and intention for behaviour. Thus, social-psychological models can be chosen for their validity in predicting dietary behaviours and in explaining behavioural change. However, they are more limited in explaining and predicting actual behaviour when prospective and more objective measures of food consumption are applied (e.g. food diaries and/or food frequency questionnaires). Subsequently, an online survey based on the TPB addressed to adults living in Italy was developed and proposed to a representative sample of Italian adults. The survey aimed at identifying the most relevant predictive variables explaining the intention to adopt a sustainable diet. Significant associations were found between the TPB constructs and the behaviour measures, underlining the main role of intention and perceived behavioural control in influencing human behaviour. The application of structural equation models revealed a high capacity of the TPB to explain both the intention to adopt the behaviour and the actual behaviour. In line with the literature, the explained variance of the behaviour was lower when a more objective measure was applied.

In the final part of this Doctoral research, two Italian case studies were compared in relation to the impact of primary school children's plate waste by assessing the embedded nutritional, environmental and economic losses. In both cases vegetables were the most wasted food group, followed by fruits and bread. Conversely, protein-based dishes, (semi)unique dishes containing both starchy-based and protein-based products dishes, and desserts were the least wasted. Overall, after adjusting for plate waste data, most of the lunch menus fell below the national energy and nutrient recommendations. The (semi)unique dishes, starchy food and protein-based dishes were found to be the most carbon emissive food categories. Moreover, a significant quota of the total waste CO_2 burden was ascribable to the agricultural and processing phases, these being the most emissive steps along the school meal supply chain. The different food composition of plate waste of the two case studies affected not only the relative carbon emission burden, but also the associated economic cost and the cost per meal. A relevant share of the entire budget for food procurement was spent on food that was discarded by children.

In conclusion, by identifying the drivers of consumers' behaviour and the associated beliefs, the findings of the TPB study may support policy makers in recommending and defining primary prevention interventions for enhancing consumer awareness and engagement towards more sustainable dietary habits. In particular,

based on the obtained results, interventions targeting the adult population in Italy should be addressed at improving their attitude and perceived control over the behaviour. Providing more information on the product labels, increasing the food variety in collective catering, and reducing the price of sustainable food products are strategic measures recommended to achieve this objective. On the other hand, important recommendations to minimise the discarded food may emerge from the children's plate waste study, i.e. supporting food educational programs in primary schools, defining school governance for healthy and sustainable eating habits, addressing teachers' attitude during the school lunch and school catering management in serving lunch menus, monitoring children's plate waste over time, and finally rethinking national guidelines for standard portions.

Chapter 1
General Introduction

1.1 Actual scenarios: a global health and nutritional perspective

According to WHO estimates, approximately 3 billion people worldwide suffer from low-quality diets, with 1.9 billion adults being in a condition of overweight or obesity, and 821 million being undernourished in 2017 (WHO, 2018). The so-called "triple burden of malnutrition", consisting of undernutrition, micronutrient deficiencies, and overweight and obesity, affects childhood in opposite terms, with 41 million and 149 million children under 5 years in a condition of overweight or chronic undernourishment, respectively (WHO, 2019). While undernutrition is mainly impacting low- and middle-income countries, the incidence of overweight and obesity is increasing in all regions (Ford, Patel, & Narayan, 2017).

In the 21st century, mortality and morbidity due to non-communicable diseases (NCDs) have been representing one of the main challenges for development. WHO estimated that worldwide, in 2016, NCDs (mainly cardiovascular diseases, cancer, chronic respiratory diseases and diabetes) were responsible of the 71% of the deaths (78 million), and caused 15 million of premature deaths claiming people from 30 to 70 years. Low- and middle-income countries showed a disproportionate burden accounting for 78% of all NCD deaths and 85% of all premature deaths, which in all countries affect the poorest and most marginal groups of the society, as the most venerable (WHO, 2018).

The aetiology of NCDs is complex, involving genetic, behavioural and environmental factors (Shuldiner, 2008). Globally, unhealthy diet and poor nutrition constitute the main risk factors of cardiovascular diseases (e.g. heart attack and stroke), certain types of cancer and diabetes (WHO, 2018). More specifically, high level of cholesterol, blood pressure and glycaemia can be mentioned as proximal causes, while tobacco, poor diet, physical inactivity, and alcohol misuse represent intermediate causes. Furthermore, urbanisation, population aging and globalisation can be listed as distal determinants. Market force has facilitated the spreading of obesogenic products driving down the costs of highly processed and energy-dense food, with a high fat content and poor nutritional value, including salty and sugary foods (Ford *et al*., 2017; Hawkes, 2006). Furthermore, technology innovation, labour mechanisation and social media have contributed to sedentary lifestyles. To counteract the increasing prevalence of NCDs and premature mortality, effective cross-sectoral and multi-level

interventions addressing key risk factors, such as malnutrition, have been indicated as the most valuable strategy to apply.

A holistic approach and a deep transformation targeting the food systems are required not only to tackle the multiple burden of malnutrition, but also to reach the UN 2030 Agenda for Sustainable Development Goals, which are intrinsically linked to the reduction of environmental impacts due to the rapid changes in food production and consumption patterns (HLPE, 2017a).

1.2 Food systems and the challenges to sustainability

Food system can be defined as the set of "all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the output of these activities, including socio-economic and environmental outcomes" (HLPE, 2014). Figure 1 offers a conceptual framework of the food systems and food environment constituents embracing the physical, economic, political, and socio-cultural contexts within which consumers choose, purchase, prepare and consume food (HLPE, 2017a). The so-defined food environment plays a central role in fostering healthy and sustainable eating behaviours.

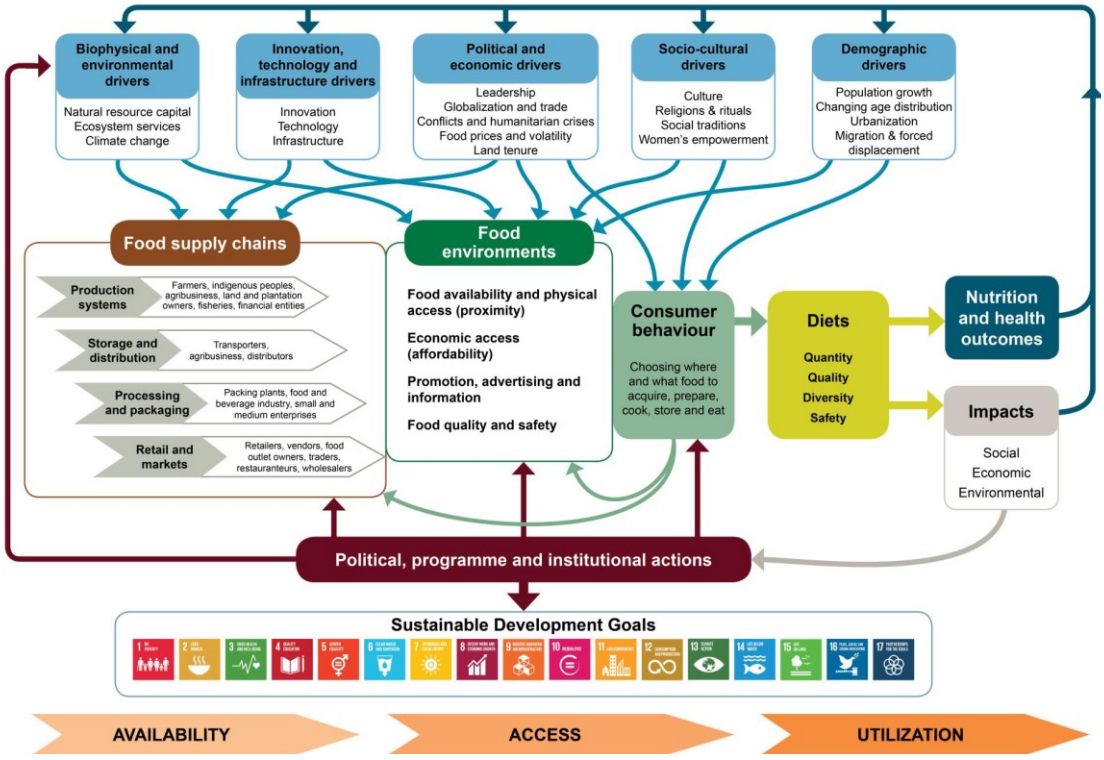

Figure 1. Food systems schematisation (HLPE, 2017a).

The conceptual framework reported in figure 1 highlights the role of consumer behaviour in the modulation of nutritional and health outcomes, as well as the social, economic and environmental impacts deriving from dietary patterns. Consumers are capable to drive food systems towards sustainability by means of their food choices, which in turn are influenced by the food environment, including food availability, affordability, availability of information, etc. The relative importance of the environmental, technological, political/economical, and social drivers may change according to the considered food system, the involved actors, as well as the political framework (HLPE, 2017; Nesheim, Oria, & Tsai, 2015).

Food systems are currently facing multiple challenges ranging from the environmental, and socio-economic dimensions, which are threatened by several factors, including food insecurity, resource exploitation and climate change. Due to the interconnections between these components, a wide analytical approach is required. Population dynamics mainly driven by population growth and urbanisation, as well as rising incomes, are leading to an increase in the demand for processed food, animal-source food, fruit and vegetables mainly in urban areas, where 55% of the world's population is now living. Today the most urbanised regions are America, Europe and Oceania, where 82%, 74% and 68% of the population is living in urban areas, respectively. Conversely, approximately half of the Asian population and 57% of African population are rural (UN, 2018). According to the estimates, the proportion of the global urban population will rise up to 68% by 2050 (FAO, 2017; UN, 2018), while the global rural population, now around 3.4 billion, is expected to decrease up to 3.1 billion (UN, 2018). Such demographic changes will affect global economy increasing the influence of low- and middle- income countries. Nevertheless, although social and economic inequalities among countries have recently declined due to rapid growth in emerging economies, inequality levels within the majority of countries have worsened, suggesting that global disparities will likely to persist in the next future (FAO, 2017). In parallel to the effect on food consumption patterns, urbanisation and higher incomes have determined a shift in employment with more people employed in the downstream sectors of the food chain, e.g. food processing, retailing, wholesaling, transport and vending, compared to those working in agriculture (FAO, 2017; Cohen & Garrett, 2010).

Food production constitutes the leading determinant of environmental change, being responsible for up to 30% of greenhouse gas (GHG) emissions (Vermeulen, Campbell, & Ingram, 2012) and 70% of fresh water use, with agriculture that occupies more than one-third of global cultivatable land (Ramankutty, Evan, Monfreda, & Foley, 2008; Foley *et al*., 2005; Willett *et al*., 2019). Globally, agriculture is a major determinant of the disruption of nitrogen and phosphorous cycles, with livestock being a major force due to its increases in terms of quantity and intensity (Steinfeld *et al*., 2006). Environmental pressure from food production derives also from the extension of cropland and pasture, which are threating biodiversity (Tilman *et al*., 2017), and from marine and aquaculture systems. Globally, marine fisheries have undergone to a general declining trend since 1996, with approximately 60% and 30% of fish stocks being respectively fully fished and exploited beyond the biological sustainable levels (FAO, 2018). On the other hand, the rise in aquaculture production can have a detrimental impact on coastal and terrestrial ecosystems (Martinez-Porchas & Martinez-Cordova, 2012).

To better ensure food security for present and future generations worldwide, food systems need to satisfy increasing and evolving dietary needs for a growing global population in a sustainable way. Climate change, estimated higher pressure on natural resources, increased GHG emissions, further deforestation and land degradation, water scarcities, as well as diversified needs and social inequalities constitute the main challenges to food system's development (HLPE, 2017b; HLPE, 2016).

According to the High Level Panel of Experts (HLPE), a food system is sustainable if it "ensures food security and nutrition for all in such a way that economic, social and environmental bases to generate food security and nutrition of future generations are not compromised" (HLPE, 2014). Based on this definition, physical and economic access to food, as well as a nutritionally adequate food intake are intended either as an outcome and a means to sustainability, meaning that these elements should not be considered as trade-off, but instead as complementary goals (HLPE, 2014; HLPE, 2017).

1.3 Food waste reduction as one of the main global challenges

To date, a univocal definition of food waste and food loss is lacking. Edibility and the possibility to avoid food loss and waste represent the criteria used for food

classification, but these criteria depend on physical, cultural and contextual elements (Corrado *et al*., 2019; Redlingshöfer, Coudurier, & Georget, 2017). According to FAO, it is possible to define food wastage as a reduction, in terms of quality (nutritional value) and quantity (dry matter) of food originally intended for human consumption, along the supply chain. Then, a distinction is made between food loss and waste. The former refers to food deterioration during agricultural production, postharvest and processing phases, while the latter entails the food which is discarded at the retail sector, by food service providers, or directly by the consumers (FAO, 2013).

According to the FAO estimates, one-third of the food produced for human consumption is lost or wasted along the supply chain. Food losses at the agricultural level represent the highest amount of food wastage globally (33%) showing similar percentages across regions (FAO, 2013). Distinguishing upstream (until storage phase) from downstream food wastage, the former accounts for 54% of the total amount and mostly affects low-income regions, while the latter is relatively more significant in high–income countries (FAO, 2013). In particular, the share of food waste at the consumption level ranges from 31% to 39% in high-income countries and from 4% to 16% in low-income ones.

Food waste, due to spillage or breakage, spoilage and discard, is driven by a multitude of determinants. Among these, technological, cultural, and legislative factors, as well as product- and person-related ones can be mentioned (Canali *et al*., 2017). Their relative importance is often context-related. In the wealthiest economies consumer behaviour, misconception of the meaning of "best before end", too strict quality standards (e.g. excluding food with flaws, uncommon size, colour and shape) are the main drivers of food waste (FAO, 2013). According to a recent literature review (Corrado & Sala, 2018), the amount of food waste ranges globally between 194 and 389 kg per person per year, while across Europe a narrower variability has been estimated (158-298 kg per capita per year).

The environmental and economic costs embedded in food waste increase along the food chain, due to the additional resources required during processing, transport or cooking compared to the first production phase (FAO, 2013). In terms of carbon footprint, food waste accounts globally for 3.3 Gigatonnes of carbon equivalent

emissions (CO_2eq); to make a comparison, this figure is just following China and USA emissions in a global ranking (WRI, 2012).

Food waste minimisation represents an urgent goal to provide adequate food to the world population and to limit the depletion of environmental, economic and human resources. The UN Sustainable Development Goals set food waste reduction target to "halve per capita global food waste at the retail and consumer level, and reduce food losses along production and supply chains by 2030". In addition, food waste prevention constitutes a priority area within the Circular Economy Action Plan proposed by the European Commission (EC, 2015).

In this context, a common methodology to quantify food waste at each step of the food chain is required. This would help to monitor the phenomenon across countries, as well as to support strategies for its prevention and reduction, identifying which streams are the most relevant and underlining which flows could be enhanced in a circular economy perspective (Corrado *et al*., 2019). In Europe, efforts addressed to harmonise food waste measurement took a concrete form in the FUSION (Food Use for Social Innovation by Optimising Waste Prevention Strategies) project which provided a quantification guide to apply at the national level and a comparative appraisal of methodological approaches (Tostivint *et al*., 2016). Subsequently, a workshop promoted by the European Commission focusing on food waste measurement was held to strengthen method harmonisation (Caldeira, Caldeira, Sara, & Serenella, 2017). However, currently, a consolidated approach for food waste accounting is still debated. The methodology of choice depends on the context (e.g. private or public), the aim of the study, the definition and type of food lost or wasted, and on its use (Corrado *et al*., 2019; Chaboud & Daviron, 2017). Based on the food chain stage, different tools can be used to collect primary data (e.g. waste composition analysis, registers at the retail sector, as well as diaries and questionnaire at the consumer level) with associated uncertainty levels. Self-reported measures, for instance, can be biased by misreporting (Corrado *et al*., 2019). However, primary data collection – considering seasonal variability able to affect food waste generation and production, as well as variations in moisture content – is important to provide robust data. Indeed, secondary data (e.g. from the literature) may lack of representativeness of the contextual conditions (Corrado *et al*., 2019). In general, a compromise between

feasibility (mainly constrained by financial resources) and robustness of the obtained data is needed (Corrado *et al*., 2019; Caldeira *et al*., 2017).

1.4 Healthy and sustainable diets

Modern nutritional science focusing on the role and mechanisms of essential micronutrients is relatively young, with the first vitamin being isolated and chemically characterised in 1926. Research was initially focused on studying nutritional deficiency-related diseases and developing strategies and guidelines to tackle deficiency conditions (e.g. beriberi, pellagra, rickets, etc.) (Mozaffarian, Rosenberg, & Uauy, 2018). The role of nutrition in the aetiology of NCDs is even more recent, with a large body of epidemiological and clinical evidence accumulated over the last decades (WHO, 2003). The reductionist (as nutrient-focused) approach initially applied to study the role of single nutrients (e.g. saturated fat, sugars) or food (e.g. fruit, meat) was extended to diet-related diseases. Only recently, the attention has shifted to evaluate the overall diet and dietary patterns (e.g. low-fat diets, Mediterranean-type diets, vegetarian diets, etc.) through large cohort studies and randomised clinical trials (Estruch *et al*., 2018; Bonaccio *et al*., 2018). The complexity of the effects of food intake and dietary patterns requires considering multiple factors, including the interactions between the nutritional components of food and how the food structure is affected by preparation and processing. This approach emphasises the beneficial health outcomes associated to the adoption of plant-based diets rich in low-processed foods, such as fruit and vegetables, pulses, wholegrain cereals, nuts, and oils rich in unsaturated fatty acids (Lynch, Johnston, & Wharton, 2018). In parallel, the consumption foods with a high sugar, salt, and saturated fatty acid content has been discouraged.

In recent decades, the role of diet has been considered in a wider perspective, by highlighting not only its impact on health, but also its strict link with the environment and the availability of natural resources. The awareness of the interconnection among human health, environment and food systems lead to the first conceptualisation of sustainable diets in 1986 (Gussow & Clancy, 1986). Gussow and Clancy recognised the need to implement dietary guidelines considering the impact of food choices on the food supply and global resources, along with the individual nutrition and health dimensions (Gussow & Clancy, 1986). An exhaustive definition of sustainable diets was subsequently provided by a Panel of international experts, as follow: “Sustainable

diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (Burlingame & Dernini, 2012). As shown in Figure 2, this concept encompasses a multitude of interrelated components and subcomponents, determinants and processes, ranging from food availability and accessibility to food choices, which in turn are affected by socio-cultural, demographic and socio-economic variables, as well as consumer attitude (Johnston, Fanzo, & Bogil, 2014; Kearney, 2010). All these elements contribute equally to diet sustainability (Johnston, Fanzo, & Bogil, 2014). The adoption of sustainable diets aims to promote environmental and economic stability and support public health, by means of affordable, accessible and culturally sensitive food, together with adequate nutrition (Burlingame & Dernini, 2012). An increasing interest has been addressed to the study and promotion of sustainable diets as an opportunity to fight poverty and food insecurity. In addition, most European countries, and more recently other Latina American (e.g. Brazil) and middle East countries (e.g. Qatar), integrated sustainability-related considerations in their national dietary guidelines (van Volksgezondheid, 2011; Brazil, 2014; Seed, 2015; Livsmedelsverket, 2015).

Figure 2. Sustainable diets at a glance (Johnston, Fanzo, & Bogil, 2014).

The wide conceptual framework of sustainable diet offers the opportunity to consider win-win scenarios and possible trade-offs across determinants when attempting to improve the diet impact on public health, environment, and socio-economic dimensions.

Several studies have shown examples of these unintended and compensating effects between multiple objectives (e.g. environmental and socio-economic goals). For instance, although controversial opinions exist, organic systems can be mentioned as a concrete example of these trade-offs. Compared to conventional agriculture, organic farming systems have been associated to environmental (e.g. higher energy efficiency, lower soil degradation, higher biodiversity preservation potential, etc.) (Smith *et al*., 2019), socio-economic (e.g. higher work opportunity in farming, greater profitability), and socio-cultural benefits (e.g. strengthened cooperation among producers and social interactions) (Prihtanti, Hardyastuti, & Hartono, 2014; Mendoza, 2004). However, due to lower yields compared to conventional agriculture (9%-25%), it is questioned if the adoption of organic agriculture on a large scale would be a valuable answer to tackle both food security goal and environmental boundaries (e.g. avoiding to threat world's forests and grasslands) (Trewavas, 2001; Pickett, 2013; Smith, Kirk, Jones, & Williams, 2019). Similarly, it is generally recognised that buying "local food" provides ecological, socio-economic and health benefits. However, "global food" has shown better performance in relation to the mitigation of the climate change (e.g. due to transport efficiency or a shorter maturing period), as well as in terms of affordability to the final consumer (Schmitt *et al*., 2017). Despite these controversial and interconnected effects, a multitude of sustainable dietary patterns have been proposed, ranging from vegetarian, pescatarian, and the Mediterranean Diet (Aleksandrowicz, Green, Joy, Smith, & Haines, 2016; Tilman & Clark, 2014), to those following national dietary guidelines and those in which (ruminant) meat is (partially) substituted by other animal-sourced or plant-based products (Aleksandrowicz *et al*., 2016). In early 2019, the Eat Lancet Commission defined global targets assessing a "safe operating space" addressed to food systems, and described a global reference diet being healthy and environmentally sustainable. This reference diet is flexible having margins for adaptability and can be tailored based on contextual scenarios. It is rich in fruit and vegetables, whole grains, pulses, nuts, unsaturated oils and includes no or a low quantity of red meat, processed meat, sugars, refined cereals, as well as

starchy vegetables. More recently, an expert consultation promoted by FAO and WHO developed Guiding Principles on what characterises sustainable and healthy diets and how such diets can be implemented in a context-specific way (FAO, WHO, 2019).

1.5 Metrics for diet sustainability

The broad characterisation of sustainable diets hinders the elaboration of appropriate, well-defined and interdisciplinary metrics for their assessment (Jones *et al*., 2016). The challenge is how to prioritise and operationalise the different components associated with sustainable diets when it comes to measure them. The large majority of the studies aimed at evaluating the consequences of dietary patterns focused on a single sustainability dimension, which is mainly related to the environmental impact (Jones *et al*., 2016). More recently research has embraced multiple multi-dimension and multi-indicator analysis, allowing the identification of potential trade-offs (Chen, Chaudhary, & Mathys, 2019). In addition, only few contributions were carried out in low or middle-income regions since high-income countries represent the preferential setting for empirical studies. The impact of different dietary patterns can be assessed by using dietary scenarios analysis. The outcomes of dietary choices can be estimated through forecast (e.g. based on current trends) or backcast scenarios (e.g. base on a set target) (Hallström, Carlsson-Kanyama, & Börjesson, 2015; Alcamo, 2008). The combination of data derived from food production and consumption with those related with environmental, economic and nutritional dimensions allows to estimate dietary changes (Hallström, Carlsson-Kanyama, & Börjesson, 2015; Alcamo, 2008). A multitude of indicators can be applied to assess the sustainability of food systems and diets. The most used are listed by category as follows.

Nutrition and Health indicators. Aside from the energy and nutrient intake evaluation, dietary quality and diversity are frequently considered in the framework of dietary intake assessment, as reported in a recent systematic review (Eme, Douwes, Kim, Foliaki, & Burlingame, 2019). An example is represented by the Healthy Eating Index, an indicator developed for the US population and used to measure the compliance of actual food consumption patterns with the US dietary guidelines (Pickett, 2013). The adherence to the Mediterranean diet (MD), associated by several studies with significant nutrition and health benefits (Schwingshackl *et al*., 2017; Becerra-Tomás *et al*., 2019), may be also assessed using several indexes or scores

differing in terms of the considered food components or lifestyle factors, and analytical approaches (Bach *et al*., 2006). Diet diversity evaluation is instead particularly relevant as a measure of food accessibility of a person or household. Furthermore, it is able to inform on the food and nutrition security status in a population (Kennedy, Ballard, & Dop, 2015). Diet related-morbidity (e.g. chronic disease risk and non-communicable disease risk) and mortality are the main historically used health indicators (Jones *et al*., 2016). More recently, the Disability-Adjusted Life Year (DALY) has been applied as additional health indicator. Given the WHO definition, it is possible to conceptualise DALYs as the cumulative number of years of life lost due to premature mortality, poor health or disability (WHO, 2016).

Environmental indicators. The environmental impact of diets is commonly evaluated by means of life cycle assessment (LCA) analysis, a standardised approach to quantify the environmental impact of a product, process, or service (ISO, 2006a,b). All phases from the cradle (primary production) to the grave (waste disposal) of the life cycle of a product are included. A multitude of environmental indicators have been proposed and applied to evaluate the food and diet environmental impact. Among these, carbon dioxide-equivalent greenhouse gas emissions (GHGe), which accounts for CO_2, N_2O and CH_4, are the most measured, followed by land use, water use, and energy use (Jones *et al*., 2016). The choice of the functional unit to use is particularly relevant to compare studies. The quantity or volume of food consumed or produced is generally used to express the associated environmental impact. In this case, the distinction between fresh, dried or cooked food is essential due to the different relative water content (Elinor Hallström & Börjesson, 2013). Alternatively, the economic value or the volume of required natural resources can be used (Schau & Fet, 2008). Furthermore, to discriminate the varying nutritional profiles of foods, the energy or protein content, as well as other nutritional indices and reference intake levels can be applied (Schau & Fet, 2008). This latter approach is preferred to compare animal-based foods with plant-based products which are generally less energy dense than animal source food due to a higher water content (Vieux, Darmon, Touazi, & Soler, 2012). Moreover, ideally all the processes contributing to food weight reduction (e.g. food loss and waste) from production to consumption, including deductions due to inedible parts, should be considered (Hallström *et al*., 2015).

Socio-economic indicators. These indicators can be applied at the individual (e.g. consumers, small-scale farmers, processors, etc.) and community scale. They mainly focus on the purchasing power taking into account lifestyle conditions and socio-economic factors, such as the Price Index, income level, wealth and social equity measures. Indeed, the measurement of poverty and inequality constitute relevant assessment as both can affect the affordability of sustainable dietary patterns (Eme *et al*., 2019). Similarly, an economic analysis of costs and benefits for producing and consuming sustainable foods in a dietary context is generally recommended (Johnston, Fanzo, & Cogill, 2014). From a social perspective, there is a significant knowledge gap in the evaluation of the dietary shift effects on communities' cultural heritage and skills, equity, rights, and governance (Jones *et al*., 2016). This information is crucial for evaluating pros and cons at community level of dietary changes towards more sustainable patterns.

1.6 Strategies for promoting healthy and sustainable diets

A set of actions towards the adoption of sustainable diets, falling within the environmental limits of "the safe operating space" (Willett *et al*., 2019), represents the main challenge for the next future to feed and nurture a growing population at global level. To reach this goal, the involvement of different actors within the food systems, including civil society, academia, and the institutional bodies at different scales (i.e. local, regional, national and international), is essential to change dietary habits and the food production methods in this direction. Modifications towards sustainable food systems are therefore feasible, even if hard to grasp.

According to the Nuffield ladder model, the interventions differ for their intrusiveness ranging from soft (i.e. providing information) to hard (e.g. restricting or precluding choices), which strongly affects the associated rate of change. Soft interventions at population-level include for instance public information campaigns, educational initiatives, dietary guidelines development, and food labelling addressed to raise awareness in consumers (Bailey & Harper, 2015). However, to allow an extensive overhaul of food system, actions at the consumer level need to be complemented with wider and intrusive legislative and regulatory interventions. Multiple supply chain steps, not only food production and consumption, but also intermediate phases such as processing, distribution, storage, and food service, need to be involved (Willett *et al*., 2019). A particular attention should be addressed to

collective catering that can more directly exert cultural influence on consumption habits. Fiscal measures on food prices provides outcomes with different efficacy in case of subsidies or taxes application. To this regards, a recent meta-analysis reported a higher effect in food intake from subsidies compared to taxes (Afshin *et al*., 2017). Indeed, the results showed that a 10% increase in the price of unhealthy foods (e.g. sugar-sweetened beverages) through taxation leaded to an average reduction of 6% in the consumption of these products, while by reducing the price for healthy foods (e.g. fruits and vegetables) to the same extent through subsidies, the relative intake incremented by 12% (Afshin *et al*., 2017). Nevertheless, the authors of a virtual supermarket experiment in New Zealand suggested that probably a combination of both strategies might be the best approach to improve population diets (Waterlander *et al*., 2019).

In the Global Burden of Disease Study (Afshin *et al*., 2019) it has been hypothesized that dietary policies to be effective should not be limited to single nutrients, such as sugar and fat, but they should address multiple food and dietary components that are not optimally consumed. Indeed, suboptimal diets for a range of food and dietary components are determinants of death and disability. Although differences can be found across countries, diet-related risks determined 22% of all deaths and 15% of all DALYs among adults worldwide in 2017 (Afshin *et al*., 2019). More than half of these deaths and two-third of such DALYs were attributable to three dietary factors, such as high intake of sodium, sub-optimal intake of whole grains, and low fruit consumption (Afshin *et al*., 2019). Priorities differ between low- and high-income societies. Overall, the former need actions to reduce food loss (e.g. improving logistics and food storage) and to increase food accessibility (e.g. improving infrastructure), variability (e.g. seasonality) and affordability, whereas the latter mainly need to foster healthy food choice and reduce food portions. In both contexts, the access to unhealthy food should be limited by defining stricter standards for food procurement targeting different age groups (Willett *et al*., 2019).

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Chapter 2
Aim of the Doctoral Thesis

Sustainable diets are aimed at promoting and supporting psycho-physical health and social well-being for actual and future generations by means of accessible, safe, healthy, environmental friendly, affordable, fair and acceptable food. Shifting dietary habits towards healthy and sustainable dietary patterns has been proved to represent a drive of change for more sustainable food systems, besides exerting beneficial effects on health outcomes and contributing to the mitigation of the climate change scenario. Given the degree of intrusiveness, hard approaches represented by fiscal and restrictive measures endorsed by the government are potentially more effective compared to soft interventions. However, their implementation over time is more difficult and may face reluctance from industries. A wider support has been instead addressed to less intrusive strategies aimed at raising awareness and empowering the final consumer. Soft approaches have been proven to exert modest successful in influencing behavioural modifications at individual level given the heterogeneity of contexts and target populations in terms of socio-demographic characteristics and socio-economic background. Tailored solutions need to be developed by applying strategies at multi-level involving different sectors within the food system. The complexity of dietary behaviours and the influence of a wide range of intrinsic and extrinsic determinants on dietary choices require a multidisciplinary approach addressing sensory, psychosocial, cognitive and environmental stimuli. In this framework, the application of psycho-social models to understand and predict healthy and sustainable eating behaviour can represent a valuable technique to design effective interventions.

Based on these considerations, the aim of the present Doctoral Thesis is to provide recommendations for the development of effective intervention strategies addressed to improve the sustainability of food choices and diet in childhood and adulthood.

Two specific targets were set to pursue this objective:

1. Identifying and investigating the relationship among personal, social and environmental factors able to affect the adoption of a sustainable diet in adult populations, within a social-cognitive theoretical framework.
2. Assessing children's eating behaviours by investigating the sustainability outcomes of their plate waste in the framework of institutionalised meals in primary schools. A multi-dimensional approach addressing the nutritional, environmental and economic dimensions was applied.

Based on these specific goals, the research activity of the present Doctoral Thesis was characterised by two phases.

During the first part, a systematic review analysed the scientific literature in terms of three socio-cognitive theoretical models to try and identify the main drivers and barriers of behavioural change towards sustainable diets in adult populations (Study 1. *Understanding, promoting and predicting sustainable diets: a systematic review*). Subsequently, based on the findings of this systematic review and on a preliminary qualitative phase (i.e. in-depth interviews and focus groups), an online survey was administered to a representative sample of adults in Italy. This cross-sectional study aimed to outline the main determinants (and the relationship between them) of the individual's intention to adopt a sustainable diet and the behaviour itself (Study 2. *Sustainable diets in Italian adult residents: an online survey*).

The second part of this Doctoral Thesis focuses on the assessment of eating behaviours of primary school children by quantifying the amount of food they discard when the school lunch is served. Two Italian case studies were selected and compared by evaluating the nutritional, environmental and economic impacts of children's plate waste. Parma and Lucca City Councils, as well as the school catering services held in the two municipalities, provided their support for this study, which is part of the Strength2Food Project funded by the European Union's Horizon 2020 research and innovation programme. (Study 3. *Nutritional, environmental, and economic impact of school lunch plate waste by children: a comparison between two Italian case studies*).

Chapter 3
Selected Studies

Study 1

Understanding, promoting and predicting sustainable diets: a systematic review

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Abstract

Background. The investigation and the understanding of consumers' behaviours are crucial for developing strategies and educational interventions necessary to transition towards more sustainable diets at the individual and population level. In this regard, social-psychological models can be effective in identifying and understanding the role of the cognitive constructs behind the consumers' behaviour.

Scope and Approach. The present systematic review is aimed at identifying the main drivers and barriers towards the adoption of sustainable dietary behaviours in adult populations. Sixty papers were analysed by applying at least one of the following three theoretical approaches: the Theory of Reasoned Action, the Theory of Planned Behaviour, and the Social Cognitive Theory.

Key Findings and Conclusions. Most of the studies were conducted in industrialised countries and only one of the nutritional, environmental and socio-economic dimensions was considered in each study. The adoption (or the intention to adopt) a healthy or a low-fat diet was the most analysed. A multitude of significant predictors of intention and behaviour was found. The most recurrent predictors were attitude for intention and intention for behaviour. Social-psychological models can be relevant when applied to dietary behaviour contexts, but present limits in explaining behaviour when prospective and more objective tools to assess food consumption (e.g. food diaries and/or food frequency questionnaires) are used. By identifying the drivers of consumers' behavioural changes, the collected results may support policy makers in providing recommendations and defining primary prevention interventions which enhance consumer awareness and engagement towards more sustainable dietary habits.

Keywords. sustainable diets, eating behaviour, theory of reasoned action, theory of planned behaviour, social cognitive theory

3.1.1 Introduction

The adoption of healthy and sustainable diets together with the transition to sustainable food production systems is urgently needed to counteract the double burden of non-communicable diseases and climate change. Sustainable diets are defined by FAO as "those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (Burlingame & Dernini, 2012). By the middle of the century, greenhouse-gas emissions, nitrogen and phosphorous pollution, biodiversity loss, and water and land use are predicted to worsen due to the current dietary trends and the projected population growth. The EAT-Lancet Commission has applied and quantified, at a global scale, the concept of a safe operating space for food system by defining scientific targets to promote human health and a stable Earth system (Willett *et al*., 2019). A universal healthy reference diet can be defined as a plant-based diet mainly composed of fruits and vegetables, whole grains, pulses, nuts, unsaturated fatty acids, whereas it provides low quantities of fish products and white meat, and no or a low amount of red meat, processed meat, added sugar, refined grains, and starchy vegetables (Willett *et al*., 2019). In this framework, the investigation and the understanding of consumers' behaviours towards food choices are crucial in defining educational and behavioural interventions to transition the diet at an individual and population level. In this respect, a valuable strategy is the application of social-psychological models to identify and understand the cognitive constructs associated to behaviours. Reference drivers and barriers towards sustainable diets could be explored by using three different theoretical models: the Theory of Reasoned Action – TRA (Fishbein & Ajzen, 1975) and its evolution in the Theory of Planned Behaviour – TPB (Ajzen, 1991) and the Social Cognitive Theory – SCT (Bandura, 1977), on sustainable dietary behaviours. These theoretical frameworks are intended to predict human behaviour as driven by: (i) considerations regarding its likely consequences (behavioural beliefs), (ii)perceived opinions of the social environment (normative beliefs), (iii) individual perceptions of barriers and facilitators existing when attempting to perform the behaviour (control beliefs), (iv) observing others within the

context of social interactions, experiences, and outside media influences. These theories have also been proved to be among the most solid theories to ground evidence-based interventions on, including health-related behaviours (Fishbein & Ajzen, 2010). For instance, interventions based on the evidence from TPB studies should be directed at modifying salient beliefs to produce corresponding changes in: attitudes (i.e. beliefs about the consequences of engaging in a certain behaviour and evaluation of these perceived likely outcomes), subjective norms (i.e. perceptions of expectations from significant others and motivation to comply with those perceptions), and perceived behavioural control – PBC (beliefs about the resources and capacity to enact the behaviour). These changes, in turn, may further influence intentions in the desired direction (Fishbein & Ajzen, 2010). Similarly, according to SCT, the behaviour arises from an interdependent interaction between subject-, behaviour- and environment-related factors. Moreover, people are capable of modifying the environment according to their desires. In this perspective, key SCT concepts are outcome expectations (beliefs about the consequences of performing a behaviour), self-regulation (ability of self-control through goal setting, self-monitoring, self-reward, environmental structuring), observational learning (acquisition of new behaviours via modelling), and self-efficacy (confidence in having skills to perform the behaviour) (McAlister *et al*., 2008).

Therefore, in this systematic review, we aim to identify the main drivers of behavioural change towards sustainable diets by examining scientific contributions that apply TRA, TPB or SCT as theoretical frameworks. In addition, we also wish to provide an updated and comprehensive overview of intervention strategies for promoting sustainable diets, to highlight the successes and failures of the interventions, as well as to identify uncertainties, gaps, and needs in research.

3.1.2 Methods

This systematic review was carried out following the PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). As the research consists in secondary literature source, no ethical approval was required.

3.1.2.1 Study identification

A comprehensive search of the literature was performed between August and September 2018 using three different electronic databases: PubMed, Scopus, and Web of Science. The search queries were differentiated according to the selected databases

and composed by a combination of keywords and terms as follows: ("theory of planned behave*" OR "social cognitive theory" OR "theory of reasoned action") AND (intent* OR attitude* OR eat* OR consumption OR intake OR choice OR habit* OR pattern OR prefer*) AND (diet* OR food OR drink* OR beverage OR nutri* OR snack*). The literature search was extended to records published by September 2018 and included contributions written in English, Italian, Spanish and French. No other temporal or spatial filters were applied to the search. As a consequence, all the articles were considered, independently from the year of data collection or publication.

3.1.2.2 Study selection

Two independent researchers assessed the papers using a 3-step strategy, performing data extraction using a standardized form, while discrepancies were solved by discussing with a third party. Firstly, articles were screened for eligibility by title and abstract. Those that met the inclusion criteria were recorded for full-text evaluation and data extraction. The exclusion criteria for article screening and eligibility were indicated as follows: conditions in which the food consumption referred to third parties, transient physiological (e.g. pregnancy, post-partum period), and specific pathological conditions (i.e. cardiovascular diseases, diabetes, and mental disorders) for which cognitive factors of eating behaviour may not be generalizable to the community at large. To retrieve meaningful results for the general healthy adult population, studies where participants were drawn from a specific population (e.g. ictus or cancer survivors, people undergoing haemodialysis, substance users, the homeless) or were not in adulthood (18-65y) were excluded to limit the heterogeneity of the recruited samples. However, if the age range of the recruited sample was not explicitly indicated, but the mean or median age was in the adult range, the paper was retrieved. Studies were not included if: (i) the investigation was addressed to alcohol or dietary supplement intake; (ii) the target behaviour and primary outcome was weight loss or weight loss maintenance; (iii) the dietary behaviour represented a therapeutic treatment (e.g. adopting a gluten-free or Dietary Approaches to Stop Hypertension - DASH diet). With regard to the "dieting" behaviour, *a priori* exclusion was not performed as different connotations are reported in the reviewed literature. Thus, only the papers which provided a definition of behaviour not consistent with a healthy and sustainable dietary behaviour were excluded (e.g. pills, liquid diet formula, or medications intake to control body weight). Additional exclusion criteria were

extended to studies considering just food purchase, from a retailer or at a restaurant, food preparation or food handling without predicting or directly analysing the intention to consume or consumption of more than one food category. The intention or behaviour analysis restricted to the activities prior to the consumption or referring to a single product, meal, food group, or food category may not be adequate in representing the adoption or the intention to adopt a sustainable dietary pattern. For this reason, studies limited to fruit and vegetables, cereal-based products, dairy products, meat or fish products were not included. For consistency, sustainable dietary behaviours, such as "avoiding fast food consumption" or "sugared snacks and drinks" were retrieved since they refer to multiple food groups/categories. Due to the relevance of domestic food waste in term of sustainability issues, the papers aimed to reduce food waste in the household context, which include the reuse of food leftovers, were included, notwithstanding the exclusion/inclusion criteria already mentioned.

3.1.2.3 Data extraction

Studies included in this review are peer-reviewed papers describing original investigations that applied three behavioural models (i.e. TRA, TPB, and SCT) to sustainable eating behaviours referred to consumption and/or post-consumption activities (i.e. food waste dimension) within the food supply chain. Distinct attributes of sustainability are considered encompassing the nutritional, environmental and socio-economical dimensions (Burlingame & Dernini, 2012). For each article included in the review, the following data were recorded: author(s), year of publication, editorial details, aim of the study, study population (sample size, age, gender distribution, period of data collection, and country of residence, socio-demographic characteristics, BMI), research methodology (i.e. qualitative and/or quantitative), applied theoretical model(s), study design, analysed constructs (i.e. independent and dependent variables), if any tools were applied to measure the dietary intake, the effectiveness of the intervention (if applied), and associations between outcomes and subjects characteristics. Exhaustive details of the screening process can be found in the PRISMA flow-Chart (Figure 1).

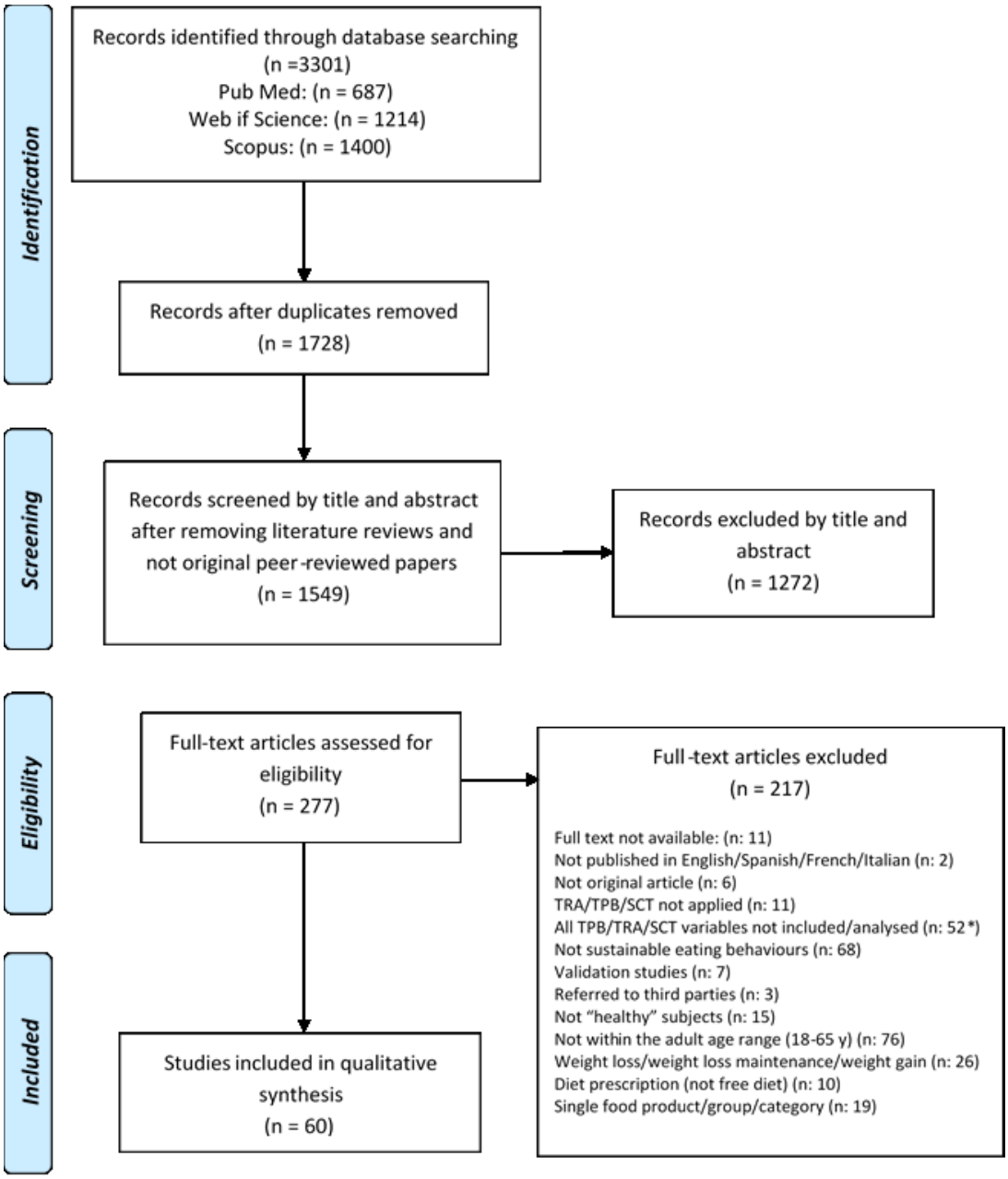

Figure 1. Flow diagram of study selection.

3.1.3 Results

A total of 3301 records were identified. After removing 1573 duplicates, 179 reviews and non-original peer-reviewed papers, 1549 studies were screened and 1272 excluded based on title and abstract. From 277 eligible full texts, 60 were finally retrieved. Table 1 summarises the totality of the reviewed studies. Most of these studies were conducted in industrialised countries, primarily US (n=22) followed by Western Europe (n=17), while only a small proportion refers to upper-medium (n=2)

or low (n=2) income countries and rural areas (World Bank Classification, 2017). The original or an adapted model of TRA, TPB and SCT were applied respectively in 2, 43[1] and 4 studies, while 12 papers refer to a combination of different behavioural models. Due to the broad extension of the sustainability concept, several investigation aims can be observed, even though most of the reviewed studies refer to the nutritional dimension (n=52/60). Research areas and objectives range from the food quality dimension (e.g. local, organic, fair trade food consumption) to healthy food choices (e.g. reducing sugar and/or fat intake, increasing calcium intake, incorporating glycaemic index into dietary behaviour) and to the food environmental impact (e.g. engagement in pro-environmental behaviours such as the adoption of plant-based diets, or reduction of household food waste). The study population included heterogeneous subjects with different health status and socio-economic conditions (e.g. age, income). They ranged from healthy subjects to individuals at risk for coronary heart diseases or diabetes, as well as overweight and obese people. Various study designs were applied, ranging from observational – cross-sectional or prospective – to intervention studies. The applied methodology included qualitative and/or quantitative research approach. A summary table of all reviewed studies is reported as supplementary material (Section 5).

Table 1. Summary of the studies included in the systematic literature review.

Authors (year)	Country(ies)	Applied model(s)	Sustainability dimension
Ajzen & Sheikh (2013)	USA	Ext TPB	Nutritional (avoid fast food consumption)
Alexander *et al.* (2018)	USA	Mix	Nutritional (healthy eating)
Armitage & Conner (1999)	UK	TPB	Nutritional (low-fat diet)
Armitage *et al.* (1999)	UK	TPB	Nutritional (low-fat diet)
Åstrøm & Rise (2001)	NO	Ext TPB	Nutritional (healthy diet)
Bassett-Gunter *et al.* (2015)	CA	TPB	Nutritional (healthy eating)
Bassett-Gunter *et al.* (2013)	CA	TPB	Nutritional (healthy eating)
Bebetsos (2002)	GR	TPB	Nutritional (healthy eating)
Blue (2007)	USA	TPB	Nutritional (diabetes-related beliefs)
Brouwer & Mosack (2015)	USA	Ext TPB	Nutritional (healthy diet)
Byrd-Bredbenner *et al.* (2011)	USA	SCT	Nutritional (dietary behaviour)
Carrete and Arroyo (2014)	MX	Mix	Nutritional (healthy eating)
Chevance *et al.* (2017)	FR	TPB	Nutritional (healthy eating)
Close *et al.* (2018)	USA	TPB	Nutritional (healthy diet)

[1] The number of papers applying TPB is 42. However, since one publication (Onwezen *et al.*, 2014) reported two investigations, the number of the reviewed studies is 43.

Conner *et al.* (2003)	UK	TPB	Nutritional (healthy eating)
Conner *et al.* (2000)	UK	TPB	Nutritional (low-fat diet)
de Bruijn *et al.* (2008)	NL	TPB	Nutritional (SFA reduction)
Goodwin & Mullan (2009)	AU	Ext TPB	Nutritional (glycaemic index)
Hagger & Chatzisarantis (2006)	UK	TPB	Nutritional (dieting)
Hagger *et al.* (2007)	UK	TPB	Nutritional (dieting)
Hagger *et al*. (2006)	UK, MY	TPB	Nutritional (dieting)
Karpinski & Milliner (2016)	USA	TPB	Nutritional (healthy diet)
Krummel *et al.* (2002)	USA	SCT, HBM	Nutritional (cardiovascular health)
Kvaavik *et al.* (2005)	NO	TPB	Nutritional (eating behaviour)
La Barbera *et al.* (2016)	IT	TPB	Food waste
Lin (2013)	TW	TPB	Environmental
Liou and Bauer (2007)	USA	Mix	Nutritional (obesity risk reduction)
Liou *et al.* (2014)	USA	Mix	Nutritional (obesity risk reduction)
Liou *et al.* (2011)	USA	Mix	Nutritional (obesity risk reduction)
Lv and Brown (2011)	USA	TPB	Nutritional (calcium intake)
Manios *et al.* (2007)	GR	Mix	Nutritional (prevention osteoporosis)
Masalu & Åstrøm (2003)	TZ	TPB	Nutritional (avoid sugared snacks/drink)
Masalu & Åstrøm (2001)	TZ	TPB	Nutritional (avoid sugared snacks/drink)
McGee *et al.* (2008)	USA	SCT	Nutritional (healthy eating)
Mondéjar-Jiménez *et al.* (2016)	IT, ES	TPB	Food waste
Mullan and Xavier (2013)	AU	TPB	Nutritional (SFA reduction)
Nguyen *et al*. (JCH) (1996)	CA	Ext TPB	Nutritional (low-fat diet)
Nguyen *et al*. (PHN) (1996)	CA	TPB	Nutritional (low-fat diet)
Onwezen *et al*. (2014)	NL	Ext TPB	Food quality (organic/fair trade)
Øygard & Rise (1996)	NO	TPB	Nutritional (healthy eating)
Pawlak *et al*. (2009)	USA	TPB	Nutritional (healthy diet)
Paisley & Sparks (1998)	UK	TPB	Nutritional (low-fat diet)
Paisley *et al.* (1995)	UK	TPB	Nutritional (low-fat diet)
Peng (2009)	USA	Mix	Nutritional (healthy diet)
Povey *et al.* (2007)	UK	TPB	Nutritional (healthy diet)
Romeike *et al.* (2016)	NL	Mix	Nutritional (healthy eating)
Ruhl *et al.* (2016)	USA	Mix	Nutritional ((un)healthy eating)
Vayro & Hamilton (2016)	AU	TPB	Nutritional (limit discretionary choices)
Visschers *et al.* (2016)	CH	TPB	Food waste
von Meyer-Höfer *et al.* (2015)	DE, CN	TPB	Food quality (organic food)
Russell *et al.* (2017)	UK	Mix	Food waste
Saunders & Rahilly (1990)	USA	TRA	Nutritional (dieting)
Shukri *et al*. (2016)	UK	Ext TPB	Nutritional (low-fat diet)
Strong *et al.* (2008)	USA	SCT	Nutritional (health behaviours)
Sumodhee & Payne (2016)	UK	TPB	Nutritional (eating pattern transmission)
Tami *et al.* (2012)	USA	SCT	Nutritional (dietary behaviour)
Thomas & Mcintosh (2013)	USA	TPB	Food quality (local food)
Tull *et al.* (2013)	BB	TRA	Nutritional (healthy diet)

White *et al.* (2010)	USA	Mix	Nutritional (healthy eating)
Wyker & Davison (2010)	USA	Mix	Nutritional (plant-based diet)

AU: Australia; BB: Barbados; CA: Canada; CH: Switzerland; CN: Chile; DE: Germany; ES: Spain; Ext: extended; FR: France; GR: Greece; IT: Italy; Mix: mixed models; MY: Malaysia; MX: Mexico; NL: Netherlands; NO: Norway; SFA: saturated fatty acids; TW: Taiwan; TZ: Tanzania.

In The following paragraphs the results will be displayed subdividing them according to the applied theoretical framework, the study design and the targeted sustainability dimension. In each section the nutritional dimension will be discussed first, distinguishing "healthy eating", from "dieting" and other restrictive (e.g. adopting a low fat diet) or more defined (e.g. considering glycaemic index) nutritional behaviours.

3.1.3.1 Original TRA model

3.1.3.1.1 Cross-sectional quantitative studies targeting healthy and nutritional sustainability dimension

The original TRA model was applied in 2 separate scientific contributions one investigated the intention to consume fruit, nuts, and vegetables in Barbadian women (Tull *et al*., 2013), the other the intention to reduce sugar and fat intake in college students enrolled in health courses in USA (Saunders & Rahilly, 1990). In relation to the two total samples, the TRA model explained respectively 19% and 41% of the variance in intention to engage in the behaviour. In the latter study, higher percentages were found when the students were split in health majors (45%) – who were studying to become health professionals – and non-health majors (47%). Both attitude and subjective norms were significant predictors, with family playing a major role in affecting dietary intentions in the sample living in West Indies (Tull *et al*., 2013). Conversely, attitude was more influential than subjective norm in predicting behavioural intention in the subsample of health majors (Saunders & Rahilly, 1990), indicating a higher relevance of beliefs and values compared to social influences in health majors — than in the counterpart. The authors (Saunders & Rahilly, 1990) suggest that the higher degree of awareness about the positive consequences of healthy nutritional behaviour may explain such results. Thus, the importance of the role of a deep-rooted knowledge in affecting health-related intentions is emphasised.

3.1.3.2 TPB or extended TPB model

Of the 42 studies applying the TPB model, 39 present a quantitative research approach. Of these, 38 are observational studies characterised by a cross-sectional (n=25) or a prospective study design (n=13), for which the study duration ranged from one week to eight years. The remaining one is an experimental study with a follow up of three months. The target population is mainly represented by young adults and university students followed by adult workers, and households composed of parents having adult children, or couples without children.

3.1.3.2.1 Cross-sectional quantitative studies targeting healthy and nutritional sustainability dimension

Within the quantitative cross-sectional studies assessing intention to eat healthy, the explained intention variance evaluated applying hierarchical multiple regression analysis ranged from 32% (Øygard & Rise, 1996) to 77% (Sumodhee & Payne, 2016), respectively in Oslovian young adults and UK mothers. Attitude represented the most relevant predictive construct both in Oslovian sample and in UK mothers. A narrower range of explained variance in intention was observed when an extended TPB model was used. The variance reached a minimum of 45% in adults living in the UK recruited from general population (Povey *et al*., 2007)[2] whereas it reached a maximum of 76% (Blue, 2007) in US adults at risk for diabetes because of family history of the disease, overweight and the occurrence of diabetes during pregnancy. To increase the predictive power of the model and to assess the impact of two further measures of social influence, descriptive norms and perceived social support were added as both additional and moderator variables for the UK sample (Povey *et al*., 2007). The most significant predictors of intention were attitude followed by PBC, whilst perceived social support acted as a moderator. In the other study, the intention to eat healthily was not significantly influenced by the additional construct, represented by perceived risk for diabetes (Blue, 2007). A relatively higher explained variance in the intention to healthy eating was also reported by Bebetsos and colleagues (Bebetsos *et al*., 2002). In this case, role identity and attitude strength towards healthy eating were added to the model applied to university students in Greece. However, only PBC and role identity positively impacted the students' behavioural intention (Bebetsos *et al*., 2002).

[2] The researchers applied a prospective study design, however, the healthy eating intention was cross-sectionally assessed.

In a cross-sectional study applying eating behaviour instead of intention as final dependent variable, the TPB model provided extremely low explained variance percentages (3-8%) (Chevance *et al*., 2017). The multiple regression analysis was conducted independently for the subjects recruited from the general population and for obese adults, adding implicit attitudes to TPB variables. In the whole sample, intention significantly predicted behaviour recorded with a self-administered food questionnaire (Chevance *et al*., 2017). A cross-sectional study applied to dieting intention used self-identity, physical self-concept, and social physique anxiety as independent constructs. All the constructs were significant predictors of intention, with the exception of subjective norms (Hagger & Chatzisarantis, 2006).

Within the nutritional sustainability dimension of the diet, the quantitative cross-sectional studies dealing with more defined behavioural intention and/or behaviour than "healthy eating" presented heterogeneous results. A TPB model was applied to predict the intention to avoid sugared snacks between meals in Tanzanian students (Joyce Rose Masalu & Åstrøm, 2003) and to predict the intention to make dietary change and reduce fat intake in adults living in the UK (C. Paisley *et al*., 1995). In the former, the explained variance reached 25%, indicating subjective norms followed by attitudes as the significant predictive constructs. In the latter, the explained variance differed on the basis of the specified dietary change, ranging from 23% in correspondence to the increase of fruit and vegetable intake to 61% for fat intake reduction. Attitude and subjective norms were also significant predictors for each dietary change considered. Four papers applying extended TPB models evaluated the intention to follow a restrictive (or specific) dietary pattern (Goodwin and Mullan, 2009; Nguyen *et al*., 1996; Shukri *et al*., 2016; Ajzen and Sheikh, 2013). The highest explained variance was obtained by Shukri and colleagues who indicated the intention to eat a low-fat diet in the following week as the dependent variable. The relative explained variance was 63%, with several independent variables acting as positive significant predictors: attitude, self-identity, injunctive and descriptive norms, gender, and past behaviour. Conversely, not only job demands, but also the interaction of injunctive norms and work interference with family acted as negative significant predictors. Conversely, job demands and work interference with family in interaction with injunctive norms acted as negative significant predictors (Shukri, *et al*., 2016). The same intention, but referred to a broader time extension (4 months instead of next

week) was evaluated by Nguyen and colleagues (Nguyen *et al*., 1996) who obtained a lower explained variance (51%), equal to that reported by Goodwin and Mullan (Goodwin & Mullan, 2009), who predicted the intention of university students to perform behaviours, such as shopping, recommending, cooking/eating, related to the glycaemic index of food. However, when the intention was restricted to cooking and eating meals with a low glycaemic index, the explained variance lowered to 30% (Goodwin & Mullan, 2009). Direct and indirect determinants of intention in adults living in Quebec were included in the multiple regression analysis. However, TPB core constructs, perceived advantages of performing the behaviour, as well as the perceived power of control factor significantly increase the explained variance (Nguyen *et al*., 1996). The supplementary variables considered for the students were glycaemic index knowledge and past behaviour. However, only past behaviour was a significant predictor together with attitude and subjective norms when the predicted behavioural intention referred to shopping, recommending, and cooking/eating all combined while only attitude and subjective norms were significant predictors when the behavioural intention was limited to cooking/eating behaviour (Goodwin & Mullan, 2009). As already described for less defined eating behaviour, when the regression analysis was made on behaviour instead of intention, an extremely low explained variance was obtained, as reported in a study referred to saturated fat intake (10%) that was significantly predicted by PBC and intention, the effect of which was moderated by habit strength (de Bruijn *et al*., 2008). Different results were instead found by Mullan and Xavier who obtained a higher explained variance for behaviour compared to intention (27% vs 19%) (Mullan & Xavier, 2013).

3.1.3.2.2 Cross-sectional quantitative studies targeting other sustainability dimensions

Considering the quantitative cross-sectional studies addressed to other diet sustainability dimensions, five papers can be listed (Mondéjar-Jiménez *et al*., 2016; Onwezen *et al*., 2014; von Meyer-Höfer *et al*., 2015; Lin, 2013; Visschers *et al*., 2016). Among them, a model of pro-environmental behaviour in diet was studied in a sample of adults living in Taiwan, showing a significant positive influence of attitude and PBC on intention (Lin, 2013). The studies included the reduction of meat consumption over the previous month, the purchase of locally produced fruit, and the in home-storage of refrigerated foods beyond the expiry date. However, pro-environmental behaviours

were not significantly affected by intention and PBC, meaning that although the subjects were aware of climate change and intended to change their lifestyle, they hardly linked dietary behaviour to climate change. For food quality dimension, the intention to consume and the consumption of organic products were evaluated in two publications (von Meyer-Höfer *et al*., 2015; Onwezen *et al*., 2014). The variance explained by the extended TPB model decreased moving from intention to behaviour. This happened for both German (56% → 53%) and Chilean (32% → 17%) subjects (von Meyer-Höfer *et al*., 2015), as well as for Dutch people (59% → 48%) (Onwezen *et al*., 2014). The additionally used TPB constructs were information, convenience, egoistic and altruistic motives, price and scepticism both acting as barriers towards the behaviour. Of these, scepticism negatively influenced both intention and behaviour, which was also negatively affected by price in the German sample. On the other hand, information and price significantly and negatively impacted behaviour in Chile (von Meyer-Höfer *et al*., 2015). In the Dutch study the feelings of guilt and pride were added as further constructs to the model, acting both as independent and dependent variables. Of these, only guilt significantly affected intention, together with attitude, injunctive and descriptive norm (Onwezen *et al*., 2014).

The remaining two quantitative cross-sectional studies dealt with food waste (Mondéjar-Jiménez *et al*., 2016; Visschers *et al*., 2016). The explained variance in intention to avoid food waste was higher than that reported for behaviour (38% vs 33%) (Visschers *et al*., 2016), for which the explained variance reached relatively small percentages in both the studies (22% and 33%, respectively reported by Mondéjar-Jiménez and colleagues, and by Visschers and colleagues. An extended TPB model was applied and a list of variables was considered. In one of the two studies (Visschers *et al*., 2016), perceived health risks negatively impacted intention, suggesting that those who perceived higher risks when consuming leftovers, a lower intention to avoid food waste was reported. On the contrary, personal and financial attitude, PBC, personal norms and use of bio waste container positively affected the intention to avoid food waste. Being female, younger, having children and having more than two adults at home resulted in more food waste compared to their counterparts. Moreover, financial attitude, PBC, personal norms, and intention to avoid food waste negatively impacted food waste behaviour (Visschers *et al*., 2016). In the second study, concerns about food waste, moral attitude and PBC significantly

predicted the intention of reducing the amount of food waste. Subjective norms, followed by intention and PBC were instead the most significant predictors of a correct behaviour towards food waste. However, some environmental factors during shopping (e.g. special offers, appealing packaging, product layout) were able to contrast positive food waste behaviour (Mondéjar-Jiménez *et al*., 2016).

3.1.3.2.3 Prospective quantitative studies targeting healthy and nutritional sustainability dimensions

Of the 14 reviewed quantitative prospective studies applying TPB, 6 referred explicitly to (healthy) eating (Armitage *et al*., 1999; Bassett-Gunter *et al*., 2013; Brouwer and Mosack, 2015; Conner *et al*., 2003; Kvaavik *et al*., 2005; Povey *et al*., 2007), while 2 dealt with dieting intention and behaviour (Hagger *et al*., 2007; Hagger *et al*., 2006). With regard to dieting, the applied models explained 67% (Hagger *et al*., 2006) and 56% (Hagger *et al*., 2006) of the intention, with higher variability in explained behaviour (66% and 32%, respectively). In both studies, attitude followed by subjective norms and PBC significantly predicted intention, which was the unique significant predictor of self-reported dieting behaviour, as assessed through two items referring to the previous 2 (Hagger *et al*., 2007) or 4 weeks (Hagger *et al*., 2006), after participants completed the initial study measures. With regards to the healthy eating, the study duration differed significantly in the 6 reviewed studies, ranging from less than 1 week (Brouwer & Mosack, 2015) to eight years (Kvaavik *et al*., 2005). The highest explained variance in intention and behaviour was observed by Conner and colleagues (Conner *et al*., 2003) who reported the results separating the sample in subjects with higher and lower ambivalence with regards to the attitude about healthy eating. For the subjects who reported lower ambivalence, the model explained higher intention (87%) and behaviour (81%) compared to the counterpart (72% and 61%, respectively). The healthy eating behaviour was assessed through a 20-item self-administered questionnaire and an FFQ. Attitude, subjective norms and PBC significantly predicted intention in both groups, while the behaviour was significantly influenced by PBC and intention in subjects with mixed feelings and by PBC and attitude in people with more defined feelings.

Splitting the recruited subjects by gender, divergent results were obtained indicating lower explained variance in men, when compared to women in relation to various eating behaviours, with the exception of added sugar intake (Kvaavik *et al*.,

2005), and higher explained variance in healthy eating intention, fruit and vegetable consumption, as well as fat intake in men compared to women (54% vs 41%; 19% vs 17%; 6% vs 14%, respectively) (Bassett-Gunter *et al*., 2013). In the former study FFQs were applied to assess dietary intake at each time points, while a 3-day food diary was used to record behaviour in the latter study.

Overall, when the hierarchical multiple regression analysis was applied in prospective studies using (healthy) eating behaviour instead of intention as final dependent variable, the explained variance reached lower percentages, as shown by Povey and colleagues (15%), Brouwer and Mosack (33%) (Brouwer and Mosack, 2015) and by Armitage and colleagues (30% and 39%, respectively in positive and negative induced moods) (Armitage *et al*., 1999). In the first one, the significant predictors of behaviour, which was evaluated through a FFQ, were only intention and PBC (Povey *et al*., 2007). In the remaining two studies a prospective assessment of dietary behaviour was made and an extended TPB model was selected, including healthy eater identity (Brouwer and Mosack, 2015) and self-identity (Armitage *et al*., 1999), as additional constructs. In the former, dietary behaviour was accurately evaluated using a combination of a FFQ and a 4-day food diary, while just a 3-item questionnaire was used in the latter. Healthy eater identity and PBC were significant predictors of intention (R^2=0.59), with healthy eater identity able to explain an additional 29% and 6% of intention and overall healthy eating behaviour variance, respectively, compared to those explained by the TPB core constructs (Brouwer and Mosack, 2015). On the contrary, the additional construct used by Armitage and colleagues significantly affected intention in positive and negative induced mood, but not behaviour (Armitage *et al*., 1999).

The quantitative longitudinal studies considering more specified intentions and behaviours within the healthy diet dimension range from the adherence to a low-fat diet in the previous 3 months (Armitage and Conner, 1999; Conner *et al*., 2000) to avoidance of sugared snacks (i.e. sweets and cakes) and drinks (i.e. soda) in the previous four weeks (J. R. Masalu & Åstrøm, 2001). The explained variance in self-perceived behaviour referred to low-fat diet varied from 59% (Conner *et al*., 2000) to 46% (Armitage and Conner, 1999). Intention and past behaviour had a significant independent association with self-reported behaviour in relation to eating a low fat diet (Conner *et al*., 2000). Moreover, temporal stability strengthened the influence of

intention and PBC on behaviour, therefore acting as a moderator (Conner *et al*., 2000). In the study of Armitage and Conner, the variance of self-reported behaviour explained by the TPB model slightly increased over time (t1: 46%, t2: 48%), suggesting that measuring behaviour longitudinally is comparable to measuring it simultaneously with the other TPB (Armitage and Conner, 1999). Similarly, the longitudinal prediction of behaviour using TPB variables assessed previously, provided similar proportions of variance in behaviour (39%). However, a great difference can be observed comparing the predicted explained variance in self-perceived behaviour with that obtained for eating behaviour assessed through a FFQ (t1: 7%, t2: 11%; t1 → t2: 10%). The prediction of fat intake in combination with fruit and vegetable consumption was prospectively assessed in 36 couples without children in one study (Bassett-Gunter *et al*., 2015). In women, the fruit and vegetable consumption after 6 months was significantly predicted by their consumption at baseline, while, in men, after controlling for baseline fat consumption, time-related control beliefs were independently and negatively associated with 6-month fat consumption. No association was found between behavioural beliefs and dietary behaviours, suggesting that interventions addressed to affective and instrumental beliefs might have a limited impact on eating behaviour in healthy subjects than targeting control beliefs (Bassett-Gunter *et al*, 2015). The model applied by Masalu and Åstrøm (2001) in relation to avoiding sugared snacks and drinks intake in Tanzanian students explained a relatively low level of self-reported behaviour variance (20%), with past behaviour, gender, intention and PBC as positive significant predictors.

3.1.3.2.4 Prospective quantitative studies targeting other sustainability dimensions

The remaining longitudinal quantitative study addressed the consumption of fair trade products by a sample of Dutch adults (Onwezen *et al*., 2014). All the constructs applied in the model significantly predicted intention, including anticipated pride and anticipated guilt, while just intention and PBC predicted fair trade consumption. Similarly to what already mentioned in Section 3.2.1 and 3.2.3 for other sustainability dimensions, when comparing the explained variance of intention to behaviour, a relevant decrease was obtained (from 56% to 9%) using a FFQ to evaluate the consumption frequency and self-estimated intake of fair trade products (Onwezen *et al*., 2014).

3.1.3.2.5 Experimental studies

One quasi-experimental study applying an extended TPB model investigated the effect of an intervention to increase calcium and vitamin D intake in first-generation Chinese-American women (Lv & Brown, 2011). Compared to the control group, the experimental one reached significantly higher intake of the macronutrients of interest after attending six weekly interactive lessons as well as at the follow up, showing a time and group effect. Conversely, normative beliefs and motivation to comply obtained higher scores only at the post-test, while behavioural beliefs, outcome evaluation, barriers, skills, self-efficacy, intention, and knowledge, significantly differed between groups at each time point, including baseline. At follow up, skills and outcome evaluation explained 59% of the intention to consume calcium rich-foods, while skills and behaviour were significant predictors of behaviour explaining 37% of calcium and 28% of vitamin D intake (Lv & Brown, 2011).

3.1.3.2.6 Qualitative studies

Of the 3 cross-sectional qualitative research papers applying TPB, the target population is heterogeneous encompassing university students living in Naples (La Barbera *et al*., 2016), male truck drivers (Vayro & Hamilton, 2016) and "locavores" (Thomas & Mcintosh, 2013). Different topics were addressed, encompassing the nutritional, environmental and qualitative dimension of the diet. Truck drivers were involved in a belief elicitation study in the context of fruit and vegetable consumption and discretionary choice reduction. In relation to fruit and vegetable intake, the elicited normative beliefs were all positively correlated to intention and behaviour, contrarily to control beliefs which showed only negative correlations, while for behavioural belief, related to both fruit and vegetables intake and discretionary choice reduction, opposite associations were found (Vayro & Hamilton, 2016). With regard to food waste, the most frequent positive expectations cited by the interviewed respondents were saving money, followed by lowering the environmental pollution due to the lower amount of food waste disposal (La Barbera *et al*., 2016). On the other hand, no disadvantages were expected from the food waste reduction by most of the students. Family (households, parents) followed by friends were the most significant referents that would approve the behaviour. Reducing food purchase and serving size are the most cited control factors and strategies to be applied to counteract food waste (La Barbera *et al*., 2016). In the remaining publication (Thomas & Mcintosh, 2013) local

food consumption was associated to nutritional, organoleptic, environmental and social advantages (behavioural beliefs), while family and peers were identified as important references (normative beliefs) able to affect the behaviour. Accessibility and cost were considered able to prevent the adoption of a locally sourced diet. Moreover, trust and moral obligation played a key role in promoting consumption of local food in contrast to global food.

3.1.3.3. SCT model

Among the 4 scientific contributions applying only SCT model on dietary behaviour, one used a quantitative research approach (Byrd-Bredbenner *et al*., 2011), two were characterised by a qualitative study design (McGee *et al*., 2008; Tami *et al*., 2012), and one applied both quantitative and qualitative methods (Strong *et al*., 2008). The reviewed qualitative studies applying SCT were all related to the nutritional dimension involving healthy eating and dietary change behaviour.

3.1.3.3.1 Quantitative studies

BMI, SCT concepts, energy and nutrient intake of American mothers having primary responsibility in household food related activities were assessed by Byrd-Bredbenner and colleagues (Byrd-Bredbenner *et al*., 2011). The lowest scores in healthy eating self-efficacy were associated with significantly higher intake of energy, total fat, and cholesterol. Moreover, lower fruit and vegetable consumption, dietary fibre and micronutrient intake were correlated with the lowest scores in healthy eating, self-efficacy, enjoys food-related activities and food label use, and negatively associated with the TV watching during dinner. The regression made on diet and health outcome expectations showed food label use reaching statistical significance as predictor (Byrd-Bredbenner *et al*., 2011).

3.1.3.3.2 Qualitative studies

From the focus groups conducted with lower Mississippi Delta residents (McGee *et al*., 2008), several personal and external factors were found to influence perceptions towards healthful food consumption. Health disorders and family members (especially children), friends, and physician were seen as strong motivators capable of influencing changes in dietary patterns. Specific mealtimes (i.e. dinner), weekends and holidays were considered occasions to prepare balanced meals, in contrast to breakfast time due to limited time available. Poor nutrition knowledge and

skills related to meal preparation and planning as well as portion control emerged as personal barriers to behavioural change. Conversely, food culture and nutrition education were considered relevant factors influencing dietary change (McGee *et al*., 2008). Tami and colleagues found that unhealthy eating behaviours of Arab mothers living in Texas were driven by the willingness to satisfy children's preference or by the lack of accessibility to traditional food products, limited availability, affordability, and quality of fresh products (Tami *et al*., 2012). After settling in USA, Arab mothers progressively westernised their eating habits thereby reducing the consumption of traditional products (e.g. lamb meat, legumes) and simultaneously increasing the intake of fast food, sweet products, and animal based-food, which were more affordable than in Arabic countries (Tami *et al*., 2012). Contrarily to McGee's and colleagues' report, some participants stated preferring to eat at restaurants instead of cooking at home during the weekend. A commonality is instead represented by food culture which was considered a driver towards healthy eating due to the high amount of fruit and vegetables in the traditional Arabic recipes, in contrast to the western American food pattern (Tami *et al*., 2012).

3.1.3.3.3 Studies combining qualitative and quantitative study design

A mixed methodology was applied in a study (Strong *et al*., 2008) targeting college students whose dietary patterns were overall in accordance with the recommendations, even if characterised by a low amount of fruit and vegetables and whole grain. Social support and habits were associated with health-related behaviours that worsened during the high school period, contributing to body weight increment. Inadequate self-regulatory skills, such as limited ability in planning and self-monitoring, were suggested as key limiting factors, also taking into account the fact that for those students healthy eating and physical activity were not considered relevant priorities (Strong *et al*., 2008).

3.1.3.4. Mixed models

A total of 12 studies were performed applying more than one theoretical model. Among them, 8 selected one theory between TRA, TPB and SCT combined with one of the following: health belief model (HBM), trans-theoretical model (TTM), self-regulation theory (SRT), protection motivation theory (PMT) or social determination theory (SDT). The remaining four studies used three or more theoretical frameworks (Liou and Bauer, 2007; Ruhl *et al*., 2016; Russel *et al*., 2017; Peng, 2009), using HBM,

comprehensive model of environmental behaviour, social-ecological models or prototype/willingness, and reasoned reactive models.

3.1.3.4.1 Quantitative studies

Chinese-American living in New York were assessed in two publications reported by Liou and colleagues (Liou *et al*., 2011, 2014) who independently investigated intention to engage in obesity risk reduction behaviour and the adoption of such behaviour. Dividing the subjects according to the degree of acculturation, the higher explained intention variance was obtained in Asian-identified individuals (41%), while for higher acculturated subjects the model showed the lowest explained variance (7%). Different significant predictors were found in each subgroups: only attitude in the western-identified group; subjective norm and self-efficacy in the bicultural group; perceived benefits, PBC and self-efficacy in Asian-identified subjects (Liou *et al*., 2014). The psychological variables explained 40% of overall risk reduction behaviour encompassing 19 single behaviours divided into five domains (Liou *et al*., 2011). However, when, for the whole sample, the regression analysis was applied on the eating and food context, the explained variance decreased to 20% and 31%, respectively. Discriminating for gender, age, BMI categories, and acculturation subgroups, the highest explained variance was obtained for obese people (53%) for which intention was the only significant predictor. Several variables significantly affected intention to eat healthily in female dieters and non–dieters college students (Ruhl *et al*., 2016). Attitude, nutrition knowledge and willingness to eat healthy food in contexts that may favour unhealthy eating resulted in significant predictors associated with dieters, while only attitude significantly predicted intention in non-dieters. No variable reached statistical significance as predictor of behaviour in non-dieters, while willingness and intention did for dieters. The model used to evaluate intention to follow a plant-based diet in psychology students explained 61% of the variance (Wyker & Davison, 2010). With a few exceptions, TPB constructs statistically differed across the stages of change (i.e. pre-contemplation, contemplation and preparation), with an increase of attitude and intention in each subsequent stage (Wyker & Davison, 2010). The last quantitative study reporting a combination of theoretical frameworks applied a randomised controlled experiment in which a computer game was used to promote healthy eating in young adults (Peng, 2009). Post-test nutrition knowledge specified in the game and the intention to eat a healthy diet

resulted significantly higher in the intervention group compared to the control group. At one month of the follow-up, the food pyramid knowledge decreased in both the groups, while long term effect of the game was observed on self-efficacy. Statistical analysis did not show univocal finding on perceived benefits and barriers comparing all time points, thus no long term effect of the game on these outcomes was confirmed.

Food waste intention and behaviour were assessed in an observational prospective investigation in UK adults (Russell *et al*., 2017). The longitudinal assessment of food waste representing the final dependent variable obtained higher explained variance compared to the intention (46% vs 29%) which was significantly predicted by PBC, subjective norm, and negative emotions. Habitual (past) behaviour and negative emotions significantly influenced behaviour which was also directly and negatively affected by intention. These paths indicate that experiencing more negative emotions about food waste was associated with a stronger intention to reduce food waste, but also with higher food waste behaviour (Russell *et al*., 2017). Moreover, these results demonstrate the relevance of non-cognitive factors in understanding and predicting behaviour.

3.1.3.4.2 Qualitative studies

Six qualitative studies combined mix models targeting (young) adults in various geographical areas ranging from Europe to North and South America. Major themes related to healthy eating elicited by Alexander and colleagues (2018) included motivations and strategies for eating well, as well as learning how to do it. Subthemes included the adopting of a healthy lifestyle, improving knowledge, planning and committing to food shopping and preparation, saving money, setting good examples to others (in particular children), managing body weight and promoting good health status. Thus, self-awareness, personal motivations, and social context emerged as relevant determinants capable of fostering self-determination to eating well (Alexander *et al*., 2018). In a study in Mexicans adults to understand the determinants of healthy dietary behaviours, knowledge, attitude, emotional reaction, behaviour (e.g. food selection and purchase, and external influential factors related to healthy eating were assessed (Carrete & Arroyo, 2014). Of these, attitude poorly explained self-reported behaviour. Moreover, the findings suggested that a low level of self-efficacy and high costs preclude behavioural change towards healthy eating. The intention of adopting a healthy diet was negatively influenced by low vulnerability and severity

levels which characterised young adults who selected and purchased food mainly based on sensorial attributes (i.e. texture, flavour, colour, smell and appearance) rather than the nutritional value of the products (Carrete & Arroyo, 2014). A convenience sample of American rural women was recruited to assess their perception on how to prevent cardiovascular disease and investigate behavioural changes for cardiovascular health (Krummel *et al*., 2002). Poor awareness of personal cardiovascular risk, family preference for unhealthy food, cultural food patterns, sensorial aspects (i.e. taste), cost and lack of support from family or friends were major barriers to a heart-healthy diet. On the other hand, initiating motivators (e.g. emotional arousal) to start dietary change and sustaining motivators (e.g. improving skills and learning) in maintaining dietary modifications were essential facilitators for behavioural change. Self-efficacy for behaviour change varied widely in the sampled women and no substantial age difference was observed (Krummel *et al*., 2002). In-depth interviewed Chinese-American young adults in New York showed their beliefs and attitude concerning obesity risk indicating dietary habits and sedentary lifestyles as the main leading factors towards weight gain (Liou & Bauer, 2007). Extrinsic factors, such as advertisements generated by media, cheap and convenience fast food products were considered as relevant drivers. In addition, higher acculturation (i.e. lifestyle westernisation) was associated to a decreased adherence to Chinese traditional food consumption that was considered healthier. Obesity was generally not perceived as an important problem for Chinese ethnicity, even if the perceived susceptibility to obesity was encountered in 60% of the respondents who mentioned poor diet, genetic factors and lack of exercise as risk factors. Strategies mentioned to prevent obesity were the reduction of portion sizes and fast food consumption, eating breakfast, and eating at home (Liou & Bauer, 2007). With regard to healthy eating, similarly as reported in other studies (Krummel *et al*., 2002; Povey *et al*., 2007), a qualitative investigation on adults of different nationalities (i.e. Moroccan, Dutch, Turkish) and living in the Netherlands provided that social support given by family, partners and children is a key factor in favouring healthy eating (Romeike *et al*., 2016). Beliefs and barriers towards healthy eating were mostly related to knowledge, attitude, social influences and PBC in all ethnic groups. Religion and culture were however discussed as influencers by Turkish and Moroccan participants, and not by Dutch people (Romeike *et al*., 2016). Beliefs related to healthy eating were also reported by White and colleagues (White *et al*., 2010) in Hispanic women living in the USA. Disease

prevention and help in reducing weight and prolonging life were mentioned among the perceived benefits of eating healthy foods. However, even if most of the respondents stated that it was easy to eat healthy food and most of them (54% of the sample) said it was not more expensive, less than half declared to eat it on a regular basis. Respondents cited lack of time and of family support (e.g. lack of a babysitter), need for transportation, and poor cooking skills as barriers (White *et al*., 2010). Manios and colleagues reported the effect of a nutrition education program targeting post-menopausal women (Manios *et al*., 2007). The intervention aimed at improving nutritional knowledge, self-efficacy towards healthy eating and osteoporosis awareness led to a higher calcium and vitamin D intake, and lower fat intake in the intervention group compared to the counterpart. Qualitative assessment (HEI scores) provided instead alternative outcomes: milk and fat HEI scores improved in the intervention group compared to the control group, while the total scores and the grains intake score increased in both the groups, even though to a higher extend in the control group (Manios *et al*., 2007).

3.1.4 Discussion and conclusions

Of the 60 reviewed papers, 52 addressed to a differentially connoted nutritional dimension therefore accounting as the most studied dimension within sustainable dietary research, whereas environmental and socio-economical dimensions have been poorly investigated in particular when TRA, (extended) TPB and/or (extended) SCT have been used. None of the reviewed studies targeted simultaneously more than one sustainability dimension, therefore being of a limit to scientific evidence due to the wide and complex challenges around sustainable diets (Burlingame & Dernini, 2012).

A wide range of explained variance of intention (7%-87%) and/or behaviour (3%-81%) can be observed comparing in the studies applying a quantitative methodology approach and targeting dietary behaviour from the nutritional point of view, across different applied models and study designs. Thus, if accurately developed and adapted, social-psychological models have the potential of being useful when applied to the eating context. However, with a few exceptions, the explained variance of behaviour was relatively lower if compared to that computed for intention, as well as when behaviour was evaluated more objectively and prospectively (e.g. using food diaries and/or FFQs). On the one hand, this can be considered a limitation of social cognitive models that might fail to fully understand and predict dietary patterns in

longitudinal studies due to the multitude of factors and discrete behaviours playing a role in determining them. On the other, a reliable assessment of behaviour is crucial in avoiding misconception in the results obtained. Therefore, albeit potentially less effective if used in social cognition models, the selection of prospective study designs and validated and accurate dietary assessment tools can be considered a valuable approach to obtaining more reliable predicting analyses on behaviour. As discussed in a previous systematic review on TPB and dietary patterns – assuming that a higher complexity in measuring behaviour leads to a higher accuracy in the estimation of *actual* behaviour – it may be that the accuracy of the link between intention and behaviour is better if expressed by lower values (McDermott *et al*., 2015). The current review confirms previous observations asserting that the intention-behaviour association is higher when behaviour is recorded through self-report measures compared to objective measures (Armitage & Conner, 2001; McEachan, Conner, Taylor, & Lawton, 2011). Accordingly, the associations between TPB variables and behaviour may be overestimated by the fact that self-perceived food consumption is likely to be biased (McDermott *et al*., 2015). For this reason, it could be interesting to combine subjective and objective dietary assessment tools to identify potential gaps between the self-perception of behaviour and its actual performance. To increase the accuracy of the results, socio-demographic factors and anthropometric variables, should be assessed and applied as moderators in the multiple-step regression analysis or structural equation models. Likewise, the assessment of other non-cognitive factors, for instance degree of acculturation, habits, and emotions, might improve the understanding of behaviour.

Overall, attitude towards the behaviour was found as the most significant predictor of intention in ten investigations. Of these ten studies, eight referred to the nutritional (healthy diet consumption and dieting behaviour), one to the food quality (organic food consumption) and one to the environmental dimension (food waste reduction). Attitude was found as the major predictor of intention for healthy diet consumption and dieting behaviour, while PBC was found as the major predictor of intention in seven studies, all involving healthy diet, except one which referred to food waste reduction. With regards to the subjective norms – one of the core constructs used in TRA/TPB – statistical relevance as intention predictor was found in several investigations. However, subjective norms had a key role as a predictor. Therefore,

interventions to change the intention to follow a sustainable diet should first of all target individuals' attitude, perceived barriers and facilitating factors, and only secondly social norms. Role identity and past behaviour emerged as important determinants since they are able to significantly explain the intention variance when used as additional constructs in different socio-cognitive models.

Intention was identified as a significant predictor in all the studies (n=16) in which behaviour was entered as the dependent variable in the multiple step regression analysis or structural equation models. However, it was not the most relevant factor in each of these scientific contributions. In some cases, subjective norms, past behaviour, self-efficacy, and socio-demographic variables (e.g. gender) achieved higher standardised regression coefficients than intention. This partially contradicts the theoretical framework, while simultaneously showing the complexity of the decision-making process which is affected by multiple intrinsic and extrinsic factors.

Qualitative investigations pointed out relevant drivers and barriers able of influencing dietary behaviour towards a sustainable direction. In this context, motivations and learning, rooted in an adequate nutritional knowledge, are essential determinants to drive the behavioural change.

3.1.5 Future perspectives

The majority of the studies was conducted in higher income economies, highlighting the need of further studies targeting low- and middle-income countries. The projected increase in income in low and middle income economies will likely increase the consumption of animal sourced foods, such as meat and dairy, therefore increasing greenhouse-gas emissions, cropland use, freshwater use, and nitrogen and phosphorus application by 50–90% from 2010 to 2050 (Willett *et al*., 2019). Therefore, more in-depth scientific evidence of the determinants capable of inducing dietary changes in these countries is essential to mitigate such environmental effects.

Raising people's awareness about the role and impact, including environmental implications, of eating behaviours at both the individual and community level, needs to be addressed in experimental studies to be effective in boosting and sustaining shifts in the desired direction. Providing tools to improve skills in planning daily activities, selecting and preparing food can be a valuable strategy to enhance the person's perceived control and ability to follow a sustainable eating behaviour characterised by a seasonal and local food consumption, as well as a limited intake of animal based-

products, as described by the EAT Lancet Commission (Willett *et al*., 2019). To improve studies on sustainable eating behaviour future research should include sustainability different sustainability outcomes to better assess sustainable dietary behaviours.

By identifying the drivers of consumer behavioural changes, the collected results may support policy makers in providing recommendations and defining primary prevention interventions which enhance consumer awareness and engagement towards more sustainable dietary habits.

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Supplementary material

Table 1. Main characterisation of the reviewed studies.

Author (year) **Study design (study duration/follow up)** **Target population**	**Sampling method** **Sample size** **% male** **Age (y)** **BMI (kg/m^2)**	**Independent variables**	**Significant predictor of intention (β) [b] {B}**	**Significant predictor of behaviour (β) [B]**	**Dependent variables (R^2) [R^2 change]**	**Behavioural outcome/measure** **Assessment tool used**
Studies applying TRA model						
Quantitative methodology approach						
Saunders & Rahilly (1990) Cross-sectional College students in USA	Convenient n=86 23% NA NA	ATT, SN	Health majors: ATT (0.67*), SN (0.07*); non-health majors: ATT (0.35), SN (0.45*).	NA	INT – whole sample (0.41); INT – health majors (0.45); INT – non health majors (0.47).	Intention to reduce sugar and fat consumption in the following two weeks Questionnaire: 1 item (likely/unlikely) Current behaviour Questionnaire: 1 item
Tull *et al*. (2013) Cross-sectional Caribbean women	Convenient n=183 0% 35.8 ± 9.1 >25 (53%)	ATT, SN	SN (0.31*) ATT (0.23*)	NA	INT (≈0.19)	Intention to consume fruit, nuts and vegetables within the following week Questionnaire: 1 item
Studies applying TPB model						
Quantitative methodology approach						
Ajzen & Sheikh (2013) Cross-sectional College students	Convenient n=51 NA [19.8] NA	ATT, SN, PBC, AA, INT	PBC [0.32**], AA [0.42**]	NA	INT [0.51]	Intention to avoid fast food Self-contained questionnaire: 3 items (plan, make an effort, intend)

Armitage *et al*. (1999) Longitudinal (1 week) University students	Not specified n=82 23% 21 (18-41 y) NA	ATT, SN, PBC, SI, INT	SI (positive MIP condition) (0.80***); ATT (negative MIP condition) (0.38**), SI (negative MIP condition) (0.50**)	INT (positive MIP condition) (0.51*); INT (negative MIP condition) (0.44*)	INT (positive MIP condition) (0.67); INT (negative MIP condition) (0.58). Behaviour (positive MIP condition) (0.30); behaviour (negative MIP condition (0.39)	Healthy eating Questionnaire: 3 items related to the previous week
Armitage & Conner BJSP (1999) Longitudinal (3 months) Adults workers	Convenient n=413 19% 37.4 (20-64 y) NA	PBC, SE, INT	NA	Self-perceived (t1): INT (0.47***); SE (0.24***). FFQ (t1): INT (-0.25***). self-perceived (t2): INT (t2) (0.53***); SE (0.22***). FFQ (t2): INT (t2) (-0.24***). self-perceived (t2): INT (t1) (0.23***); INT (t2) (0.37***); SE (t2) (0.20***). FFQ (t2): INT (t1) (-0.18*)	Self-perceived behaviour (t1--> t1) (0.46); FFQ behaviour (t1-->: t1) (0.07); self-perceived behaviour (t2-->t2) (0.48); FFQ behaviour (t2-->t2) (0.11); self-perceived behaviour (t1-->t2) (0.39); FFQ behaviour (t1-->t2) (0.10)	Eating a low-fat diet. Questionnaire on self-perceived behaviour related to the previous 3 months: 2 items; FFQ: 63 items
Åstrøm & Rise (2001) Cross-sectional Young adults from GP	Random n=735 49% 25 NA	ATT, SN, PBC, role identity; PB (healthy eating).	ATT (0.18***), PBC (0.38***), role identity (0.53***), PB (0.24*)	NA	INT (0.59)	Intention to eat healthy food in the future Mailed questionnaire survey: 1 item (likely/unlikely)

Bassett-Gunter *et al*. (2015) Longitudinal (t1: 6 months, t2: 12 month) Couples without children	Convenient n = 72 50% 24±8.40 (women), 29±5.34 (men) NA	behavioural, control, normative beliefs	NA	F&V in women, t0 → F&V in women, t1: (0.64**), control beliefs in men, t0 → fat in men, t1: (0.40, p< 0.05)	F&V women, t1: [0.41], fat men, t1: [0.16]	F&V and fat consumption (t1) 3-day food records at each time point
Bassett-Gunter *et al*. (2013) Quantitative Longitudinal (t1: 6 months, t2: 12 month) Parent and non-parent adult couples	Convenient n=209 48% 32.1 (women), 30.1 (men) NA	Affective ATT, instrumental ATT, SN, PBC, INT	healthy eating: women, parent status (-0.22**), affective ATT (0.38**), PBC (0.27*), SN x parent status (0.32*); men, Affective ATT (0.55**), SN (0.16*), PBC (0.15*)	Fat intake t2: women, fat (t1) (0.38**), PBC (−0.24*); men; fat (t1) (0.38**), PBC (-0.25*) F&V intake t2: women (F&V, t1) (0.39**), men: F&V (t1) (0.38*)	Men: INT (healthy eating) (0.54), F&V intake (t2) (0.19), fat intake (t2) (0.16); women: INT (healthy eating) (0.41), F&V (t2) (0.17), fat (t2) (0.14)	Intention to eat heathily and dietary intake 3-day food records at each time point
Bebetsos *et al*. (2002) Cross-sectional Physically active university students	Convenient n= 96 25% 20.3±2.6 NA	ATT, SN, PBC, role identity, ATT strength,	PBC (0.51***), role identity (0.35**)	NA	INT (0.71)	Students' intentions and self-efficacy towards healthy eating Questionnaire for the Planned Behavior Model and the Health Behavior Questionnaire.
Blue (2007) Cross-sectional Adults at risk of diabetes	Convenient n=106 NA NA NA	ATT, SN, PBC, perceived diabetes risk	ATT (0.34*), SN (0.28*), PBC (0.44*)[3]	NA	INT (0.76)	Intention to eat healthy Mailed questionnaire: 3 items (intend, try, plan)

[3] Exact *p*-values are not available for the variables (i.e. attitude, subjective norms, perceived behavioural control and perceived diabetes risk) inserted in the model

Brouwer & Mosack (2015) Longitudinal (≥4 days) Adult women	Convenient n=79 0% 22.9 ± 6.4 25.87 ± 6.55	ATT, SN, PBC, healthy eater identity, INT	PBC [0.34**]; healthy eater identity [0.43***]	Healthy eater identity low-fat dairy (0.34*); healthy eater identity fruit (0.29*); INT vegetables (0.34**); healthy eater identity overall eating behaviour (0.38***)	INT (0.59); Healthy eating behaviour (0.33).	Food consumption and composite healthy food score 4-day food diary and FFQ: 85 items.
Chevance *et al*. (2017) Cross-sectional General population (GP) and obese adults (OA)	Convenient n=153 49% (GP); 36% (OA) 34.7 ± 8.9 (GP), 50.6 ± 12.3 (OA) 36.8 ± 4.03 (OA)	ATT, SN, PBC, INT	NA	INT (GP) (0.38*)	Eating behaviour: GP (0.08), OA (0.03)	Eating behaviour score for OA and GP (0-13, no versus all recommendations respected New Eating Self-Administered Questionnaire
Close *et al*. (2018) Cross-sectional Southeastern US Office workers	Convenient n=214 19% 43.0±10.3 NA	ATT, SN, PBC	ATT (0.19**); SN (0.17*); PBC (0.62***)	NA	INT (0.56)	Intention to eat a healthful diet in the next 12 months Questionnaire: 3 items (intend, try, plan)
Conner *et al*. (2003) Longitudinal (1 week) Adults from GP	Convenient n=232 31% [38] NA	ATT, SN, PBC, INT, AAM	Lower AAM group: ATT (0.47***), SN (0.14*), PBC (0.48***); Higher AAM group: ATT (0.41***), SN (0.13*), PBC (0.52***)	Lower AAM group: ATT (0.30*), PBC (0.64***). Higher AAM group: PBC (0.26**), INT (0.60***)	INT: lower AAM (0.87), higher AAM (0.72); behaviour: lower AAM (0.81), higher AAM (0.61)	Self-reported healthy eating behaviour (20-items) and general healthy eating behaviour FFQ: 33-items

Conner *et al*. (2000) Longitudinal (8 months, 3 time points: t0, t1, t2) hospital workers	NA n=407 NA 37.4 (20-64y) NA	ATT, SN, PBC, INT, PBC stability, INT stability	NA	INT (0.29***), PBC (0.11*), PB (0.42***), INT x INT stability (0.17**), PBC x PBC stability (0.12*), PB x PBC stability (-0.13**)	Self-perceived behaviour (0.59)	Eat a low-fat diet in the previous 3-months (self-perceived behaviour: 2-items): PB (t1), current behaviour (t2)
De Bruijn *et al*. (2008) Cross-sectional Dutch adults	Convenient n= 764 45% 44.30 ± 10.20 NA	Instrumental ATT, affective ATT, SN, PBC, INT, HA strength, INTER	NA	INT (-0.15**), PBC (-0.12**), INTER (-0.10**)	Fat score (0.10)	Saturated fat intake measured as fat score (0-80, lowest to highest fat intake) FFQ 35-questions covering 19 food items usually consumed in the previous 4 weeks.
Goodwind & Mullan (2009) Cross-sectional University psychology students	Convenient n = 72 32% 20.08 NA	ATT, SN, PBC, GI KNO, PB	ATT (cooking/eating) (0.32**), SN (cooking/eating) (0.35**), ATT (shopping, recommending, cooking/eating) (0.34***) SN (shopping, recommending, cooking/eating) (0.31**), PB (shopping, recommending, cooking/eating) (0.41***)	NA	INT: cooking/eating (0.30), shopping, recommending, cooking/eating (0.51)	Intention in recommending, shopping cooking/eating low GI meals; engagement in these behaviours in the last three months (PB): (3-items)
Hagger & Chatzisarantis (2006) Cross-sectional University students	Not specified n=250 43% 24.85 ± 6.40	ATT, SN, PBC, INT, SI, PSC, SPA	ATT (0.18**), PBC (0.17**), SI (0.56**), PSC x SI (0.19**), SPA (0.09*), SPA x SI (-0.14*)	NA	INT (0.69)	Dieting intention in the next 2 weeks Questionnaire: 2 items (plan, intend)

	NA					
Hagger *et al*. (2007) Longitudinal (2 weeks) University students	Not specified n=525 43% 22.83 ± 6.50 NA	ATT, SN, PBC, INT, personal identity, social identity	ATT (0.58**), PBC (0.14**), SN (0.27**)	INT (0.79**)	INT (0.67), behaviour (0.66)	Self-reported dieting behaviour referred to the previous 2 weeks (2-items)
Hagger *et al*. (2006) Longitudinal (4 weeks) University students	Convenient n=250 44% 24.64 ± 6.39 NA	ATT, SN, PBC, INT	ATT (0.54**), PBC (0.21**), SN (0.21**)	INT (0.57**)	INT (0.56), behaviour (0.32)	"Watching my diet" (dieting) behaviour referred in the previous 4 weeks. Behavioural frequency questionnaire (1-items)
Karpinski & Milliner (2016) Cross-sectional Athlete college students	Convenient n=291 21% 20 ±1.21 NA	ATT, SN, PBC	ATT (0.53***), SN (0.24***), PBC (0.28***).	NA	INT (0.73)	Intention to eat a healthful diet Online survey: 4 items
Kvaavik *et al*. (2005) Longitudinal (8 years) Norwegian adults in their mid-30s	Convenient n= 519 46% t0 25y → t1 33y NA	ATT, SN, PSN, PBC, INT, EDU, HI, MS, CHI, BEB	NA	F&V, t1: ATT (men) (0.20*), SN (men) (-0.15*), BEB (men) (0.31**), PBC (women) (0.14*), SN (women) (0.12*), BEB (women) (0.32**); Whole grain, t1: EDU (men) (0.14*), BEB (men) (0.25***); SN (women) (-0.16*),	F&V, t1: men (9.3), women (20.1), whole grain (t1): men (6.6), women (17.1), total fat, t1: men (3.9), women (7.1), added sugar, t1: men (13.9), women (7.1)	T0: dietary intake in young adults, T1: dietary habits (usual diet during the past year) in terms of F&V intake (g/day), whole grain intake (g/day), total fat intake (% of total E intake), added sugar intake (% of total E intake)

				EDU (women) (0.13*), BEB (women) (0.31***); total fat, t1: INT (men) (-0.20*), MS (men) (-0.17*); PBC (women) (-0.25***); added sugar, t1: PSN (men) (-0.14*), HI (men) (-0.17*), BEB (men) (0.35***), BEB (women) (0.26***)		FFQ (t0): 30-items from which 5 scores were obtained about fruit and vegetables, whole grain, fat and sugar intake, FFQ (t1): 180-items
Lin (2013) Cross-sectional Kaohsiung adult residents conducting business	Convenient N= 223 47% 30–39 (27.4), 20–29 (22.9) NA	ATT, SN, PBC, INT	ATT (0.11*), PBC(0.27***)	Not significant predictors	INT and behaviour	Previous engagement in pro-environmental behaviour Questionnaire: 3 items (meat intake reduction in the previous month; buying Taiwan-produced fruit, storing food after the expiring date)
Lv & Brown (2011) Intervention (3 months) First generation Chinese-35-55 years old American women with child(ren) in Chinese school	Convenient n = 140 0% 43.1± 4.5 exp. group; 42.3 ± 4.4 (ctrl group) NA	ATT (behavioural belief, OEv, SN (normative belief, MC), PBC (barriers, skills, SE), INT	Skills (NA), outcome evaluation (NA)	Skills (NA), INT (NA)	Experimental Group (follow up): INT (0.59) behaviour: calcium intake (0.37), vitamin D intake (0.28)	Calcium and vitamin D intake FFQ: 29 items for 29 calcium-rich foods
Masalu & Åstrøm (2003) Cross-sectional	Convenient n= 981 77%	ATT, SN, PBC	ATT (0.15***), SN (0.41***)	NA	INT (0.25)	Intention to avoid sugared snacks between meals

Tanzanian students	25 ± 3.7 NA					Questionnaire survey: 2 items (intend, plan)
Masalu & Åstrøm (2001) Longitudinal (4-weeks) Tanzanian students	Convenient n: 1123 (t0); 228 (t1) 68% 26.4 ± 4.2 (19-45y) NA	ATT, SN, PBC, PB (previous sugar avoidance), GEN, INT	ATT (0.24***), SN (0.27***); PBC (0.33***), PB (0.10***)	INT (0.19*), PBC (0.17*), PB (0.20*), GEN (0.19*)	INT (0.45), self-perceived avoidance of sugared snacks and drinks (0.20)	Current frequency intake of sugared snacks (sweet and cakes) and drinks (soda) (t0): 3-itmes. PB (t0): trying to avoid between-meal intake of sugared snacks and drinks in the previous three months (1-item). Self-perceived sugar restriction (t1): trying to avoid between-meal intake of sugared snacks and drinks in the past few weeks (1-item)
Mondéjar-Jiménez *et al*. (2016) Cross-sectional Young adults	Convenient n=300 ≈42% 20.62 ± 2.62	concern about FW, moral ATT, SN, marketing/ sale strategies addiction, PBC, INT	Concern about FW (0.14***), moral ATT (0.36***), PBC (0.23***)	SN (0.51***), INT (0.20***), PBC (0.15***), marketing/ sale strategies addiction (-0.16***)	Behaviour (0.22)	Positive (correct) behaviour towards FW Questionnaire: 3 items (regular use of leftovers in the following days; be aware of the differences between “use by” and “best before” dates; plan purchases regularly by writing a shopping list)

Mullan & Xavier (2013) Cross-sectional University students	Convenience n= 96 17% 19.65 ± 4.34 NA	ATT, SN, PBC, INT, LS, CH	PBC (0.28*)	PBC (0.42**)	INT (0.19); fat consumption (0.27)	Saturated fatty acid intake Block Food Screener and FFQ (meat and snack products)
Nguyen *et al*. JCH (1996) Cross sectional Male adult smokers	Random n= 671 100% 30-39 (37.6), 40-49 (37.6), 50-60 (24.8) NA	ATT, SN, PBC (diet), PBC (exercise), INT, age, EDU level, perception of health status, perception of stress, quantity of alcohol consumed weekly, cigarettes smoked daily (n)	NA	Age (-0.05**, -0.06**, - 0.05**, 0.02**), PBC (diet) (-0.63***, -0.61***, -0.69***, -0.16***), PBC (exercise) (-0.93***, -0.16***, 0.19***, -0.74***), cigarettes (n)/day (0.05*, 0.04*, 0.02*, 3.72E.03*)[4]	Behaviour (0.65)	Low-fat food consumption FFQ: 31-items (low-fat foods)
Nguyen *et al*. AJHP (1996) Cross-sectional 30-60 year old men	Convenient n=1839 100% 30-39y (33.3), 40-49y (35.6), 50-60 (31.1) NA	ATT, SN, PBC, BS, SEO ((dis)advantages), SNB, MC, CB, PPC	SEO (advantages) (0.23***), SN (0.28***), PBC (0.18***), PPC (0.16***), ATT (0.16***)	NA	INT (0.51)	Intention to have a low-fat diet within the next 4 month Postal questionnaire: 1 item
Onwezen *et al*. (2014) Study 1 - Cross-sectional Dutch adults	Random n=944 50% 44.9 ± 14.7 NA	ATT, IN, DN, PBC, pride, guilt, INT	ATT (0.36***), IN (0.16***), DN (0.30***), guilt (0.13***)	PBC (0.06*), INT (0.69***)	guilt (0.23), pride (0.33), INT (to purchase) (0.59); self-reported behaviour (0.48)	Self-reported organic product consumption FFQ: Organic meat, vegetables, fruit, and dairy product

[4] Data reported in brackets refer respectively to group 1 (smokers with high fat diet and lack of physical activity), 2 (smokers with an inadequate diet), 3 (smokers with a diet which needs improvement) and 4 (smokers with inadequate physical activity).

						consumption in the previous 2 months.
Study 2 – longitudinal (1 week) Dutch adults nationally representative for age, GEN, and geographic distribution	Random n=501 50% 44.7 ± 14.9 NA	ATT, IN, DN, pride, guilt, PBC, INT	ATT (0.15***), PBC (0.13***), IN (0.21***), DN (0.37**), guilt (0.11*), pride (0.11*)	PBC (0.13***), INT (0.23*)	INT (to purchase) (0.56), self-reported behaviour (0.09)	Self-reported fair trade product consumption FFQ: fair trade bananas, tea, coffee, juice, chocolate, and other foods (e.g., dried fruit and sugar) consumed in the previous week (frequency and self-estimated amount using standard portion size)
Øygard & Rise (1996) Cross-sectional young adults living in Oslo	Convenient n=527 % 23 – 26y NA	ATT, SN, PBC	ATT {0.38***}, SN {0.10**}, PBC { 0.26***}	NA	INT (0.32)	Intention to eat healthier in the following 4 weeks Questionnaire survey
Paisley & Sparks (1998) Cross-sectional High-fat adult consumers	Convenient n=152 25% 34 (18-65 y) NA	ATT, SN, PBC, perceived need (to reduce fat intake), PB, estimated fat intake	NA	NA	Expectations (0.39); perceived need (total sample) (0.37); males (0.43) females (0.36)	Dietary intake 4-day weighed dietary records; Self-estimated fat intake questionnaire: 1 out of 3 items
Paisley *et al*. (1995) Cross-sectional UK Adult consumers	Random n= 390 59% NA	ATT, SN, PBC	ATT (fat) (0.25***), SN (fat) (0.46***); ATT (cakes & biscuits) (0.21***), SN (cakes	NA	INT: reducing fat (0.61), cakes and biscuits (0.27), butter & margarine (0.32), red meat (0.29),	Intention to make dietary changes and reduce fat intake in the following year

	NA		and biscuits) (0.42***); ATT (red meat) (0.33***), SN (read meat) (0.31***); ATT (bread and potatoes) (0.29***), SN (bread and potatoes) (0.37***); ATT (F&V) (0.20***), SN (F&V) (0.37***); ATT (fat milks) (0.41***), SN (fat milk) (0.33***); ATT (fat products) (0.34***) SN (fat products) (0.33***); ATT (meat products) (0.25***) SN (meat products) (0.40***		increasing bread and potatoes (0.31), F&V (0.23) changing to reduced fat milks (0.40), fat products (0.31), fried foods (0.31)	Questionnaire: 1 item; Self-perceived fat intake Questionnaire: 1 item; Dietary intake FFQ: 92 items
Pawlak *et al*. (2009) Cross-sectional Male college baseball players	Random n=108 100% 20.25±0.11 NA	ATT, SN, PBC	ATT (0.38***), SN (0.29***), PCB (0.27***)	NA	INT (0.70)	Intention to eat a healthful diet Questionnaire: 4 items
Povey *et al*. (2007) Longitudinal (2-weeks) Adults living in UK	Random n=235 30% median age 38y NA	ATT, SN, PBC, DN, PSS, INT, ATT x DN, ATT x PSS, SN x DN, SN x PSS, PBC x DN, PBC x PSS, ATT x SN, SN x PBC, ATT x PBC	ATT (0.46***), SN (0.12*), PBC (0.22***), PSS x PBC (-0.19**), PSS x ATT (0.13*)	INT (0.18**), PBC (0.27***)	INT (0.45), behaviour (0.15)	Intention to eat a healthy diet in the future Questionnaire: 2 items (intend, want) Dietary behaviour FFQ: 63 items

Shukri *et al*. (2016) Cross-sectional Adult workers living in Malaysia and UK	Convenient n=603 47% 40.0 ± 11.1 (UK), 34.0 ± 8.5 (Malaysia) NA	ATT, IN, DN, SE, PBC, WIF, FIW, Job demands, Job resources, Culture, GEN and PB	ATT (0.16***), SE (0.18***), IN (0.11***), DN (0.14***), Job demands (-0.07**), GEN (0.07**), WIF X IN (-0.25*) PB (0.36***)	NA	INT (0.63)	Intention to eat a low-fat diet over the following week Questionnaire: 2 items Past behaviour Questionnaire: 2 items (eating 5 portions of F&V daily; eating a low-fat diet)
Sumodhee & Payne (2016) Cross-sectional Couples of mothers and adult children	Convenient n= 60 35% (children) 54±4.25 (mothers), 24±4.35 (children) NA	ATT, SN, PBC	ATT (mothers) (0.60***), PBC (0.25**); ATT (children) (0.44***), PBC (children) (0.42***)	NA	INT (mothers) (0.77), INT (children) (0.65)	Mothers and their adult children's intentions to eat healthily regularly Questionnaire: 3 items
Visschers *et al*. (2016) Cross-sectional Adults responsible for shopping and cooking at home	Random n= 796 38% 57 ± 15 NA	INT, financial ATT, personal ATT, PHR, good provider identity, PBC, PN, SN, food storage KNO, use by date KNO, use of bio-waste container, ADU, CHI, EDU, GEN, age	Personal ATT (0.25***), financial ATT (0.07*), perceived health risks (-0.09**), PBC (0.19***), PN (0.24***), use of bio waste container (0.07*)	GEN [0.09**], children at home [0.12**], more than 2 adults [0.16**], financial ATT [-0.03*], PBC [-0.09***], PN [-0.05**], INT [-0.18***], good provider identity [0.05***]	INT (0.38), behaviour (0.33)	Intention to avoid food waste Paper questionnaire; Total amount of self-reported food waste/household Questionnaire: frequency of disposal and amount of food waste disposed since spoilt or over the use-by date.
Von Meyer-Höfer *et al*. (2015) Cross-sectional	Convenient n=567 49%	ATT, SN, Egoistic motives, Altruistic motives, price,	Chilean adults: ATT (0.15*), SN (0.37**), Altruistic motives	Chilean adults: INT {0.20**},	Germany: INT (0.56) behaviour (0.53); Chile:	Intention to consume more organic food in the future

Adults living in Germany and Chile	42.4 (Germany), 38.5 (Chile) NA	scepticism, convenience, information, INT	(0.26**); German adults: ATT (0.28**), SN (0.15**), altruistic motives (0.25**), egoistic motives (0.20**), scepticism (-0.11*)	Information {-0.30**}, price {-0.12**}, German adults: ATT {0.15**}, INT {0.45**}, price {-0.12*}, scepticism {-0.22**}	INT (0.32) behaviour (0.17)	Questionnaire: 1 item Frequency of organic food consumption (actual behaviour): Questionnaire: 1 item
Qualitative methodology approach						
La Barbera *et al*. (2016) Cross-sectional Undergraduates from Naples	Convenient N= 58 64% 18.02 NA	Outcome beliefs, normative referents, control beliefs, ATT, SN, PBC	Not applicable	Not applicable	Not applicable	Beliefs related to reducing, at home, during next three months, the amount of food waste Interview
Vayro & Hamilton (2016) Cross-sectional Truck drivers	Convenient n=30 100% 39.53 ± 10.72 32.90 ± 8.47	Behavioural, normative and control beliefs	Not applicable	Not applicable	Not applicable	Modal salient belief identification about healthy eating (reduction of discretionary choice and intention and behaviour for fruit and vegetable intake. Self-report, paper-based survey
Thomas & McIntosh (2013) Cross-sectional Local diet consumers "locavores"	Random n=11 36% 30s - 60s NA	behavioural, normative, and control beliefs, trust and morality	Not applicable	Not applicable	Not applicable	Beliefs, trust and morality related to consuming a local diet Focus group interview
Studies applying SCT						
Quantitative methodology approach						

Byrd-Brenner *et al*. (2011) Cross-sectional Mothers living with partners	Convenient n=201 0% 37.9 ± 5.1 26.4 ± 5.9	SE, S-reg (sets goals, S-rew, environmental structuring), OEx	NA	NA	SE (0.26), OEx (0.08)	Dietary intake Block's Fruit/Vegetable/Fibre Screener and Fat Screener
Qualitative methodology approach						
McGee *et al*. (2008) Cross-sectional Adults in lower Mississippi Delta	Convenient n=91 7% 18-44 (37%), 45 (63%) NA	Personal (KNO and skills), behavioural (motivators/perceived benefits), environmental (social, physical) determinants	Not applicable	Not applicable	Not applicable	Factors influencing a change in healthful food consumption behaviour; eating habits description
Tami *et al*. (2012) Cross-sectional Arab mothers living in Texas	Convenient n=22 0% NA NA	reciprocal determinism, behavioural CAP, OEx, SE, observational learning, and reinforcement	Not applicable	Not applicable	Not applicable	Positive/negative shifts on dietary and physical activity behaviours after moving to USA Focus group
Quantitative + qualitative methodology approach						
Strong *et al*. (2008) Cross-sectional Young adults living in Virginia	Random n=43 49% Males:18.6 ± 0.1; females 18.1 ± 0.1 females Males: 22.05 ± 0.6; females 21.09 ± 0.6	S-reg, social support, SE, OEx	Not applicable	Not applicable	Not applicable	Healthy eating behaviours 4 day food diary record

Studies applying mixed models						
Quantitative methodology approach						
Liou *et al*. (2014) Cross-sectional Chinese American living in New York	Convenient n=300 35% 26 ± 6.8 22.6 ± 3.84	ATT, SN (NBE, MC), PBC, SE, PBE, PBA, SUS, PSE, CTA	ATT (western) (0.27*), SN (bicultural) (0.43***), SE (bicultural) (0.28**), PBC (Asian) (0.34*), PBE (Asian) (0.28*), SE (Asian) (0.29*)	NA	INT: western (0.07), bicultural (0.27), Asian (0.41)	Intention to engage in obesity risk reduction behaviours in the upcoming week Questionnaire: 1 item (plan to choose smaller portion sizes) Self-reported obesity risk-reduction behaviours during the past month Questionnaire: food context (9 items), eating context (4 items)
Liou *et al*. (2011) Cross-sectional Chinese American living in New York	Convenient n=300 35% 26.4±6.8 22.6±3.84	ATT, SN (NBE, MC), PBC, SE, PBE, PBA, SUS, PSE, CTA[5]	NA	Overall behaviours: SE (0.36**), INT (0.28**), eating context: SE (0.24**), perceived benefits (0.18*); food context: INT (0.29**), SE (0.34**), INT (male) (0.47*), SE (male) (0.23*), SE (female) (0.51*), PBE (female) (0.21*), INT (18-21y) (0.41*), SE (18-21y) (0.32*), SE (22-29y) (0.49*), CTA (22-29y) (0.28*), SE (30-40y)	Behaviour: overall risk reduction (0.40), eating context (0.20), food context (0.31), male (0.44), female (0.35), 18-21y (0.42), 22-29y (0.33), 30-40y (0.32), 18.5 ≤ BMI < 25 (0.47), 25 ≤ BMI < 30 (0.42), BMI ≥ 30 (0.53)	Practising obesity-risk-reduction behaviour Questionnaire: eating context (4 items) and food context (9 items)

[5] Associations between degree of acculturation, gender and age with overall obesity-risk-reduction behaviours were also considered in further regression analyses.

				(0.45*), SE (18.5 ≤ BMI < 25) (0.04*) PBE (18.5 ≤ BMI < 25) (0.22**), INT (18.5 ≤ BMI < 25) (0.25*), INT (25 ≤ BMI < 30) (0.43*), INT (BMI ≥ 30) (0.72*), SE (low ACC) (0.04*), PBE (low ACC) (0.34*), SE (high ACC) (0.38*), INT (high ACC) (0.37*)		
Peng (2009) Intervention (1 month) Undergraduate students	Convenient n=40 20% 20 NA	Food pyramid KNO, KNO specified, SE, PBE, PBA	NA	NA	INT (NA)	Healthy eating intention in the future Questionnaire: 10 items
Ruhl *et al*. (2016) Cross-sectional College females	Convenient n=583 0% 20.89 ± 1.85 23.70 ± 4.90 <18.5 (≈6%); 18.5-24.9 (64%); 25-29.9 (19%); >30 (11%)	Nutrition KNO, SN, prototypes, ATT, affect, INT, WIL	ATT (dieters) (0.20***); ATT (non-dieters) (0.36***); NK (dieters) (0.11***); WIL (dieters) (0.44***).	WIL dieters (0.31***); INT dieters (0.24***)	INT (NA), WIL (NA) Behaviour (NA)	Intention to eat F&V and foods with added fats and sugars Questionnaire: 3 items Food consumption FFQ: 194 foods consumed over a 2-month period
Russell *et al*. (2017) Longitudinal (14 months, (4 surveys) Shoppers living in UK	Convenient n= 172 41% 50-59y NA	ATT, SN, PCB, PB, negative emotion, INT	PBC (0.37***), SN (0.21***), negative emotions (0.16***)	INT (−0.12**), PB (0.65***), negative emotions (0.17***)	INT (0.29), behaviour (0.46)	Intention to reduce food waste in the next week Questionnaire: 2 items (intend,

						likely/unlikely reduce); Habitual food waste behaviour (PB, survey 1, 2-items) Questionnaire: 2 items (frequency and quantity of food wasted); Food waste behaviour (survey 4, 2-items) Questionnaire: 2 items (frequency and quantity of food wasted)
Wyker & Davison (2010) Cross-sectional Psychology students	Convenient n=204 42% NA NA	ATT, SN, PBC	NA	NA	INT (0.61), INT (1-unit change in ATT) (0.59), INT (1-unit change in SN) (0.46), INT (1-unit change in PBC) (0.13)	INT to adopt a plant-based diet in the following year Questionnaire: 2 items (intend; likely/unlikely)
Qualitative methodology approach						
Alexander *et al*. (2018) Cross-sectional Young adults living in metropolitan Detroit and rural Pennsylvania	Random n=68 44% 26.9 (21-30y) NA	behavioural (MO, OEx), personal (e.g. ES, PLA, MON, food preparation commitment) and environmental (e.g. PS) factors	Not applicable	Not applicable	Not applicable	Motivations, barriers and facilitators to healthy eating Focus group interview
Carrete & Arroyo (2014) Cross-sectional Mexican adults	Convenient n=30 17% 18-50y NA	ATT, KNO, ER	Not applicable	Not applicable	Not applicable	Self-reported behaviour on food selection and purchase; drivers and inhibitors towards dietary change Focus group interview

Krummel *et al*. (2002) Cross-sectional Adult women	Convenient n=34 0% 20-55y 24-34[6]	PSUP, PAW, family preferences, taste, cost, time, SE, cues	Not applicable	Not applicable	Not applicable	Facilitators and barriers to change towards a heart-healthy diet Focus group interview
Liou & Bauer (2007) Cross-sectional Chinese-American young adults living in New York	Convenient n=40 40% 22 (18-30y) NA	ATT, SN, PBC, SUS, PSE, PBE, PBA, SE, CTA, PENV, SENV	Not applicable	Not applicable	Not applicable	Beliefs, attitudes, determinants related to obesity risk and prevention. Semi-structured interview
Romeike *et al*. (2016) Cross-sectional Adults of different origins living in the Netherlands	Convenient n=90 40% 46.2 ± 12.6 NA	ATT beliefs, PSN, PBC, SS, SP, PBA and solutions	Not applicable	Not applicable	Not applicable	Beliefs and barriers that underlie socio-cognitive and planning constructs related to healthy eating Focus group interview
White *et al*. (2010) Cross-sectional Hispanic women living in South Carolina	Convenient n=31 0% 36.4 ± 11.6 NA	PBE, PFS, PBA, SE	Not applicable	Not applicable	Not applicable	Frequency of consumption of healthy foods Face-to-face interview
Quantitative + qualitative methodology approach						
Manios *et al*. (2007) Intervention (5 months) Post-meno pausal women	Not specified n=75 0% 60.0 ± 4.8 NA	PSe, PSu, call for action, PBE, PBA, SE	NA	NA	Food consumption	Dietary intake 24-h recall (quantitative assessment); Healthy Eating Index score (qualitative assessment)

[6] The data refer to BMI mean range computed for the participants in each focus group.

* p value <0.05; ** p value <0.01; *** p value <0.001; ß: standardised regression weight coefficient; B: non standardised regression weight coefficient; age data are expressed as mean ± SD, mean, [median] or age range (%). When available, adjusted coefficient are reported in the column of significant predictor factors for intention and/or behaviour. AA: anticipated affect, AAM: attitudinal ambivalence, ACC: acculturation, ADU: presence of more than two adults in the households, ATT: attitude, BEB: baseline eating behaviour, BMI: body mass index, BS: belief strength, CAP: capability, CB: control belief in skills needed to adopt e behaviour, CH: current happiness, CHI: presence of children in the household, CTA: cues to action, DN: descriptive norms, EDU: education, ER: emotional reactions, ES: eating strategies, FIW: family interference with work, F&V: fruit and vegetables, FW: food waste, GEN: gender, GI: glycaemic index, GP: general population, HA: habit, HI: household income, IN: injunctive norms, INT: intention, INTER: interaction, KNO: knowledge, LS: life satisfaction, MC: motivation to comply with the opinions of important reference, MIP: mood induction procedure, MO: motivation, MS: marital status, MON: monitoring, NA: not available, NBE: normative beliefs, OEv: outcome evaluation, OEx: outcome expectation, PAW: perceived awareness, PB past behaviour, PBA: perceived barriers, PBE: perceived benefits, PBC: perceived behavioural control, PENV: physical environment, PFS: perception of family support, PGN: perceived group norms, PHR: perceived health risk, PLA: planning, PN: personal norms, PPC: perceived power of the control factor, PS: peer support, PSC: physical self-concept, PSE: perceived severity, PSN: perceived social norms, PSS: perceived social support, PSUP: perceived support, RI: role identity, SE: self-efficacy, SENV: social environment, SEO: subjective evaluation of the outcome, SI: self-identity, SN: subjective norm, SNB: strength of normative belief, SPA: social physique anxiety, S-reg: self-regulation, S-rew: self-reward, SUS: perceived susceptibility, WIF: work interference with family, WIL: willingness.

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Study 2

Sustainable diets in Italian adult residents: an online survey

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Abstract

Background. A growing body of evidence indicates the need for a huge transformation of agri-food system to preserve ecosystems and human health, the promotion of which at the individual level is strictly link to lifestyle and dietary habits. The analysis of factors able to affect consumers' dietary behaviour in different age groups plays a primary role in fostering sustainable and nutritionally balanced food choices.

Scope and approach. By applying the theory of planned behaviour (TPB), the present study aimed at identifying the most relevant predictive psycho-social variables able to explain the intention to adopt a sustainable diet and the behaviour itself in a representative sample of adults residing in Italy. An online survey was applied involving 838 adult consumers (18-65 y, 51.8% females). The adoption of a sustainable diet was measured as perceived behaviour, as Mediterranean diet adherence (MDA) score, and as the frequency of consumption of single food groups. Structural equation modelling (SEM) techniques tested the associations of the psycho-social factors with the dependent outcomes (i.e. intention and behaviour measures).

Key Findings and Conclusions. Significant associations were found between TPB core constructs and the behaviour measures underlining the main role of intention and perceived behavioural control on behaviour. SEM explained 54-78% of variance in intention, with a lower efficacy when behaviour measures were used as dependent variables (0-54%). A medium level of MDA and a poor perception of adopting a sustainable diet were reported confirming the shift from the Mediterranean dietary pattern in Italy and suggesting how to target effective intervention strategies in Italy to drive adults towards sustainable and healthy food consumption.

Key words: diet sustainability, Mediterranean diet, theory of planned behaviour, SEM, adult population

3.2.1 Introduction

Diets not only represent the core link among food systems, nutrition and health outcomes, but also mediate the impact of agriculture and food systems on environment, economy and society (HLPE, 2017). From the environmental perspective, agriculture is mainly responsible for the greenhouse gas emissions (GHG) in terms of methane (CH_4) and nitric oxide (N_2O), while the intermediate and final steps of the supply chain contribute more in terms of carbon dioxide (CO_2) emissions due to the processing, transportation, retailing, storage and cooking of food and ingredients (Sáez-Almendros *et al*., 2013). Despite differences can be observed based on the selected unit of measurement (e.g. kg, kcal), food products can be characterised and distinguished by quantifying their environmental impact through several indicators. Among them, carbon footprint and water footprint, land and energy use as well as acidification and eutrophication potentials could be mentioned (Willett *et al*., 2019; Aleksandrowicz, Green, Joy, Smith, & Haines, 2016). Moreover, according to the food group, different contributions to the overall environmental exploitation can be associated to each step along the supply chain, with, for instance, a higher detrimental effect alternatively associated to the production phase for animal-based products, or to the distribution phase for fresh fruit and vegetables (Nemecek *et al*., 2016). From a social point of view, food systems play a major role in public health. which is strictly linked to food security and food safety. Moreover, agricultural and food production systems affect the income level and distribution of a population, playing a relevant role in the affordability of a diet (Johnston, Fanzo, and Bogil 2014). However, affording nutrient-rich foods, such as fruits and vegetables, in high income countries is becoming a significant challenge for more vulnerable households too. Local food production and food culture are strengthened in socially sustainable food chains that contribute to create social capital and trust among the actors involved in the food chains. Similarly, local food systems contribute to the economic return for producers and local communities, with the potential to preserve specific production systems and local resources, like in the case of products bearing geographical indication certifications. In general, food is part of local culture, where the types of foods, the way of preparation and eating in social contexts, are repositories of traditions and affect cultural identity (HLPE, 2017). In this context, food systems evolution is deemed to modify cultures and traditions, and *vice versa*, with relevant economic, nutritional and health outcomes for societies.

3.2.1.1 The sustainability of the Mediterranean Diet

Dietary patterns and frequency of food consumption are associated to health status, but also substantially modulate resource exploitation. Indeed, animal-based products are more energy intensive and require more resources compared to plant-based products (Baroni *et al*., 2006). In parallel, sufficient evidence of a cause and effect relationship has been established between the consumption of processed meat and cancer (Domingo and Nadal 2017; IARC, 2015). The International Agency for Research on Cancer classified processed meat as carcinogenic (Group 1), and a limited evidence of the causal link with cancer development was instead established for red meat consumption, therefore classified as probably carcinogenic (Group 2A) to humans (IARC, 2015). It has been largely proven that several health advantages can be linked to the adoption of a dietary pattern inspired by the Mediterranean Diet (MD) (Galbete, Schwingshackl, Schwedhelm, Boeing, & Schulze, 2018; Sofi, Abbate, Gensini, & Casini, 2010), whom surrounding concept underwent an evolution over time (Dernini and Berry 2015). A Mediterranean-type diet is able to prevent the development of cardiovascular disease – not only in populations living in the Mediterranean area (Galbete, Schwingshackl, Schwedhelm, Boeing, & Schulze, 2018; Dinu, Pagliai, Casini, & Sofi, 2017) – reducing the risk of diabetes (Georgoulis, Kontogianni, and Yiannakouris, 2014) and metabolic syndrome (Becerra-Tomás *et al*., 2019; (Godos *et al*., 2017). In addition, an inverse association between MD adherence and cancer risk and mortality has been demonstrated (Schwingshackl *et al*., 2017), as well as between adherence to MD and depression and cognitive impairment (Psaltopoulou *et al*., 2013), with demonstrated beneficial effects on sleep quality in the adult population (Godos *et al*., 2019). MD is a nutritionally adequate plant-centered diet, whose pillars are similar to those qualifying the global "healthy diet from sustainable food systems" defined by the EAT Lancet Commission (Willett *et al*., 2019), and grounded on the "One Health" concept, strengthening the idea that human and ecosystem health are not independent (HLPE, 2017; FAO & WHO, 2010). Both dietary approaches largely include whole grains, fruit and vegetables, nuts, unsaturated fatty acid sources (e.g. olive oil) and both limit the consumption of red meat, processed meat, starchy vegetables, added sugar and refined grains. However, a stricter limitation is addressed to fish and white meat intake in the reference diet described by the EAT Lancet Commission (Bach-Faig *et al*., 2011; Willett *et al*., 2019). If food security, affordability, accessibility and cultural acceptability are ensured, the MD emerges as

an example of sustainable dietary pattern able to address health and ecological concerns (Burlingame and Dernini, 2011), showing a lower environmental impact, richness in biodiversity, important food-related socio-cultural values, and positive economic return for local communities. As found in previous studies, the dietary shift towards a Mediterranean-type diet can lead to positive outcomes both on health and climate change (Tilman & Clark, 2014; Blas, Garrido, Unver, & Willaarts, 2019). It is worth noting that MD, acknowledged by UNESCO as an Intangible Cultural Heritage of Humanity, should not be considered just as a mere reference on which a particular set of food needs to be consumed in specified quantities and proportions, but also as a cultural model involving not only consumption, but also food production, processing, distribution and cooking, including rituals and traditions (Bach-Faig *et al*., 2011; UNESCO, 2010). On the basis of the health-promoting outcomes linked to the adoption of a Mediterranean dietary pattern, scientific efforts have been increasingly addressed to develop proper methods to estimate the adherence to MD by using indexes or scores, and to test for their disease risk predictive ability (Ruiz *et al*., 2015). Such indexes or scores can be calculated as a result from the intake of certain food components and lifestyle factors (Bach *et al*., 2006). By using *a priori* (i.e. based on the existing scientific evidence and dietary guidelines) (Bach *et al*., 2006) or *a posteriori* (i.e. based on statistical techniques, as factor analysis or cluster analysis) approaches, it is possible to define which components should be considered. This means that the Mediterranean adherence can be determined by observing the sample distribution (e.g. medians, tertiles) or by using independent criteria (e.g. dietary recommendations). The available indexes, the first being developed in 1995 (Trichopoulou *et al*., 1995), differ for the target population (e.g. living outside the Mediterranean area and belonging to varying age ranges) and the applied total range of the scores, such as from 0-8 (Trichopoulou *et al*., 1995; Woo *et al*., 2001) to 0-100 (Rumawas *et al*., 2009), with intermediate ranges like 9-27 (Schröder et al., 2004) and 5-40 (Martínez-González *et al*., 2002). The total range of the scores is in turn calculated from the components' scoring, the scheme of which is also different among the various scores (e.g. 0-1, 0-2, 0-5, etc.) (Ruiz *et al*., 2015).

In the last decades, current dietary behaviours in the Mediterranean area, including Italy (Germani *et al*., 2014), are stepping away from the MD model due to globalisation – which worldwide overcomes geographical barriers between food

productions and consumption – population growth, urbanisation, life style changes together with economic and socio-cultural factors (Sandro Dernini & Berry, 2015; Belahsen, 2014). Overall, the westernisation and homogenisation of food behaviours are weakening the sustainability of food systems and food consumption, now less rooted in population food culture and responsible for a loss biodiversity and soil degradation. A multitude of factors, ranging from food availability, accessibility and choice, which are in turn determined by personal and socio-economic factors such as consumer attitude, income and culture, variably influences food consumption (Kearney, 2010). Consumer demand has the potential to drive food systems towards sustainability, by selecting foods according to their geographical origin and production methods within the same food group or category. Investigating consumers' motivation and relative determinants to adopt sustainable dietary choices is crucial to develop strategies able to facilitate such transition. In this framework, socio-cognitive models can be applied to identify drivers and barriers towards a sustainable food consumption and to develop effective strategies to encourage the adoption of a sustainable dietary behaviour.

3.2.1.2 Theoretical framework

Among the socio-cognitive models that can be applied, the theory of planned behaviour (TPB) is one of the most suitable tools that could be used to better understand dietary habits. It derives from the Theory of Reasoned Action (Fishbein and Ajzen, 1975; Fishbein & Ajzen, 1980) that was implemented to extend its applicability beyond purely volitional behaviours by adding to the model explicit evaluations on perception of control on behaviour performance (Ajzen, 1988; Ajzen, 1991). The TPB is an expectancy-value model where attitude, subjective norm, perceived behavioural control (PBC), and intention represent the core cognitive constructs able to explain and predict a particular human behaviour. In addition, the TPB can be defined as a deliberative processing model where attitudes arise from conscious evaluations of available information (Conner and Norman, 2005). The TPB proposes that intention and PBC are the proximal predictors of a person's behaviour. Intention is the conscious motivation to exert effort to perform that behaviour, while PBC represents the subject's expectancy that putting in action the behaviour is under his/her control. Intention is in turn predicted by one person's attitude (i.e. positive or negative evaluations of performing the behaviour), by subjective norm (i.e. perception

about what significant others think the subject should or should not engage in the behaviour), and by the already mentioned PBC, which is generally employed to represent subject's control on behaviour due to the difficulties in measuring actual control for which it is a proxy measure. The more PBC reflects actual control on behaviour, the better the prediction of behaviour should be, as the subject's actual control plays a role modulating the power of intention to predict behaviour (Fishbein and Ajzen 2010). As a consequence, this power is attenuated in case of lack of control, or annulled if the constrains on action are considered as insurmountable obstacles (Martin Fishbein & Ajzen, 2010; Conner and Norman, 2005).

Each TPB construct has prior determinants. Attitudes are driven by beliefs about the consequences of the behaviour, as perceived by the subject. Two elements are at the attitude basis. i.e. the perceived likelihood of an outcome occurring as a consequence of engaging in the behaviour, and the subjective evaluation of that outcome. Subjective norm is a function of beliefs on significant others' approval or disapproval about the behaviour performance by the subject. The TPB proposes to quantify normative beliefs as the product between the subjective likelihood that important people (groups or individuals) for the subject think he/she should put in action the behaviour and to what extent is the subject's motivation to comply with that referents' expectation. PBC is dependent on beliefs related to having the necessary resources and conditions to perform the behaviour successfully, weighted by the perceived power of each element to favour or prevent the adoption of the specific behaviour. These elements include either intrinsic or extrinsic variables. The former encompass the degree of subject's information, his/her skills and abilities, as well as emotions. Extrinsic factors refer instead to external barriers or incentives, for instance money and/or time availability, accessibility to opportunities related to the performance of behaviour and limited level of independence. The rational by which behaviour can be defined as reasoned or planned is based on the important assumption that someone's intention and behaviour arise in a reasonable and consistent way from their beliefs. However, for the sake of the model, it is not relevant if these beliefs are rational or not, as they can derive from irrational processes, unconscious biases or fallacies.

The TPB has been widely applied to health-related behaviours, ranging from health-enhancing and protective behaviours (e.g. condom use, vaccinations, physical

activity performance, healthy diet adoption) (Asare, 2015; Britt & Englebert, 2018; Stolte, Hopman-Rock, Aartsen, Tilburg, & Chorus, 2017; McDermott *et al*., 2015) to health-harming behaviours (e.g. drug use, including alcohol or illicit substances, tobacco smoking, exceeding the speed limit when driving car) (Cooke, Dahdah, Norman, & French, 2016; Bashirian, Hidarnia, Allahverdipour, & Hajizadeh, 2012; Topa & Moriano, 2010; Conner *et al*., 2007; Mcmillan & Conner, 2003). In the context of healthy eating, extensive scientific literature has addressed the application of TPB to fat intake (Armitage & Conner, 1999; Shukri, Jones, & Conner, 2016; Mullan & Xavier, 2013) and fruit and vegetable consumption (Carfora, Caso, & Conner, 2016; Menozzi, Sogari, & Mora, 2015; Menozzi and Mora 2012; Bogers, Brug, van Assema, & Dagnelie, 2004). However, to the best of our knowledge, a more complex sustainable dietary behaviour, including not only health but also environmental, economic and/or social perspectives, has not yet been examined in an adult population (18-65y) by applying the TPB model. Therefore, this paper tries to fill this gap blending multiple diet sustainability dimensions, in accordance with FAO definition (Burlingame and Dernini 2012) and applying the TPB as social cognition approach.

This study aimed to evaluate the efficacy of the TPB model in explaining intention to adopt a sustainable diet (SuDiet) in a representative sample of the Italian adult population. The SuDiet was defined as characterised by "a limited consumption of animal-based products, preference towards local and/or seasonal products that are respectful of environment and biodiversity". In addition, the study predicted the behaviour itself, by using multiple outcome measures, such as the self-perceived behaviour, the overall MD adherence score, and the consumption frequency of single food groups. Indeed, the adherence to the Mediterranean dietary pattern was investigated as a proxy of actual sustainable dietary behaviour.

It was hypothesized that attitude, subjective norm and perceived behavioural control would predict intention to eat sustainably, and that intention and perceived behavioural control would predict behaviour, with self-identity playing a moderating role.

3.2.2 Materials and methods

3.2.2.1 Sample

After receiving the approval from the local Institutional Ethical Committee (Comitato Etico Area Vasta Emilia Nord, 1139/2018/OSS/UNIPR), the online survey instrument containing TPB-items and a validated 15-item questionnaire of adherence

to MD (Gnagnarella *et al*., 2018) was distributed to a representative sample of adults residing in Italy (18-65 y) by a third party (marketing company) in July 2019. The survey required approximately 15 minutes to be completed in one occasion by the respondents who provided their informed consent to the study. Only the subjects living in Italy and not affected by cardio-metabolic conditions, such as diabetes and cardiovascular diseases, as well as eating disorders, were eligible to participate in the present cross-sectional study. Indeed, for these individuals, cognitive factors may not be generalizable to the community at large and might bias the distribution of the survey outputs. The data were collected from subjects, representative of the adult population residing in Italy based on three selected criteria, i.e. gender distribution, age range, and geographical areas of residence (nomenclature of territorial units for statistic, NUTS 1).

3.2.2.2 Measures

Anthropometric and socio-demographic variables (age, sex, height, weight, nationality, region and size of residence centre, educational attainment, income, occupation, number of adults and children being in the household) were self-reported by the subjects. Moreover, the subjects were asked to express the degree of responsibility for the food purchase and meal preparation, the habitual frequency of eating out, any participation to solidarity purchasing groups/environmental associations, as well as the presence of certain physiologic status (i.e. pregnancy or breastfeeding), particular health risk factors (i.e. hypertension, dyslipidaemia) and food allergy or intolerance. Before providing the respondents with the FAO's definition of sustainable diets, the online survey included also a question addressed to understand the concepts the respondents associated more to the meaning of sustainable diets.

A preliminary qualitative phase addressed to elicit salient beliefs, including behavioural outcomes, social referents and control variables, was applied following the protocol proposed by Fishbein and Ajzen (Fishbein and Ajzen, 2010). Accordingly, a standard TPB-based questionnaire was developed based the outputs obtained from: (i) a qualitative explorative questionnaire administered to 22 postgraduate Parma University students with different academic background, (ii) one focus group performed with 6 undergraduates in food science and technology; (iii) a total of 10 interviews to adults of both genders and varying socio-demographic characteristics.

Attitude, subjective norm, and PBC represented the latent independent TPB variables for the selected behaviour (i.e. to adopt a sustainable diet). To inform these TPB constructs, direct and indirect measures were developed using specific items. The participants responded to each item on a specific 7-point scale. Direct measures consisted of un-paired scales, while indirect measures consisted of various item-pairs of scales that were multiplied to obtain a unique score. Intention and behaviour were applied as dependent variables. In parallel to the TPB constructs, self-identity was also measured.

Attitude. The direct measures of attitude consisted of 7-point semantic differential scales using four polar adjectives (i.e. the adoption of a SuDiet in the next future for me would be: not useful at all-very useful; not satisfactory at all-very satisfactory; not healthy at all-very healthy; not pleasant at all-very pleasant). After testing for the internal consistency, reliability, and convergence of the construct, the mean of the four scales was used as a composite score. Indirect attitude measures were calculated multiplying eight outcome expectancy items and the corresponding outcome evaluation items. The formers represent the perceived likelihood that salient outcomes will occur if a SuDiet will be adopted by the subject (e.g. if I adopt a SuDiet in the next future, it will contribute to reduce the environmental impact: very unlikely/very likely), while the outcome evaluation items consisted of statements measured on unipolar scale anchored by desirability (e.g. reducing environmental impact is for me not desirable at all/very desirable).

Subjective norm. To assess subjective norm two categories of normative beliefs were considered: injunctive and descriptive beliefs. The formers were used to obtain an indirect measure of subjective norm multiplying five injunctive beliefs referent items (e.g. my family think I should adopt a SuDiet in the next future: very unlikely/very likely) and five corresponding motivations to comply items (e.g. I'm interested if my family approve or disapprove my choices when it comes to food: not at all/very much). Descriptive beliefs were instead used to assess the probability that significant people will enact the behaviour in the next future. Three items were used in this case: my family/my partner/my dear friends would adopt a SuDiet in the next future. In addition, direct perceived norm scales consisting of four items (e.g. most of the people I value would approve I adopt a sustainable diet) were used to measure subjective norm.

Perceived behavioural control. Direct and indirect measure of PBC were used and a composite score was computed. Direct measures of PBC consisted of four scales (e.g. I think that the adoption of a SuDiet in the next future is under my control: absolutely no/absolutely yes; if I wanted to, I will adopt a SuDiet in the next future: very unlikely/very likely). The presence of the incipit "if I wanted to" represents a strategy to control for the possible motivational confound with the final aim to better evaluate the impact of obstacles on volitive rather than motivational dimension (Williams 2010; Bassett-Gunter *et al*., 2015). Within the four scales, one was used to measure self-efficacy: I believe that I am able to adopt a SuDiet in the next future: absolutely not/absolutely yes. On the other hand, the indirect measure of PBC was obtained multiplying five control belief factors (e.g. I will have more free time in the next future: very unlikely/very likely) and the corresponding control belief power items (e.g. having more free time would allow me to adopt a sustainable diet: very unlikely/very likely). Control beliefs assessed participants' perceptions about their ability to adopt a SuDiet in the next future despite intrinsic and extrinsic barriers.

Self-identity. It was assessed through one item measured on 7-point Likert scale anchored by absolutely not/absolutely yes: I think to myself as a person interested to diet sustainability.

Intention. As dependent latent variable, intention was measured using four items: I intend to adopt a SuDiet in the next future: absolutely no/absolutely yes; I want to adopt a SuDiet in the next future: absolutely false/absolutely yes; I will adopt a SuDiet in the next future: very unlikely/very likely; I have in program to adopt a SuDiet in the next future: I totally disagree/I totally agree.

Behaviour. As final dependent variables, two cross-sectional measures of behaviour were included to identify potential discrepancies between the self-perception of behaviour and its actual (self-reported) performance. One measure was represented by a composite score based on a 3-item self-perceived behaviour evaluation: I can say that I have adopted a SuDiet within the last 3 months; I can say that I have limited the consumption of animal-based products within the last 3 months; I can say that I have mostly consumed local and/or seasonal food products within the last 3 months. All the items were measured on a unipolar scale anchored by I totally disagree/I totally agree. The second measure of behaviour was based on a 15-item food frequency questionnaire, already validated to assess the adherence to the

Mediterranean dietary pattern on a score from 0 (minimal adherence) to 9 (maximal adherence) (Gnagnarella *et al*., 2018). Such MD index is based on *a priori* approach, meaning that it is independent from the distribution of study population. The scoring scheme of the components is binary, with a score of 0 or 1 being associated to the intake of each included food group/item. To compute the final score, the daily or weekly intake frequencies of the following food groups/items were considered: wholegrain cereals; vegetables; fruit; olive oil; red meat; nuts; pulses; wine (Gnagnarella *et al*., 2018). As MD has been proven to be a SuDiet (Dernini *et al*., 2017; Donini *et al*., 2016; Sandro Dernini & Berry, 2015), the score of MD adherence was used as a proxy to determine the degree of sustainability of the diet adopted by the respondents. Moreover, not only the overall score, but also single score of frequency of food group consumption were applied as dependent variables to better understand the relations between the TPB constructs and the dietary habits adopted by respondents.

3.2.2.3 Data analysis

Descriptive and inferential statistics was performed. Using weight and height data, subjects' BMI was computed and weight status was defined by applying WHO standard cut-offs (WHO, 2010). Initial analyses were addressed to confirm the correlations between attitude, subjective norms, and PBC with both intention and the behaviour assessments (self-perceived and actual self-reported behaviour) (Fishbein and Ajzen 2010). The internal items consistency (Cronbach's alpha) and reliability (factor loadings, λ; composite reliability, CR) were determined. To assess convergent validity, the average variance extracted (AVE) was evaluated and the confirmatory factor analysis (CFA) statistics was applied for the TPB variables and antecedent constructs.

Correlations between and within exogenous variables (i.e. attitude, subjective norms and PBC), and endogenous variables (i.e. intention and behaviour measurements) were tested running Spearman's rank-order correlation (ρ). The same test was applied to explore the correlation between self-identity/BMI and TPB constructs. In addition, by applying Mann-Whitney and Kruskal-Wallis non-parametric tests, participants were grouped based on socio-demographic/ anthropometric factors and other descriptive information, and compared in relation to their TPB constructs scores.

To examine whether and to what extend attitude, subjective norms, self-identity and PBC explained intention and behaviour, structural equation models (SEM) were tested. In particular, the role of self-identity as moderator of the effect exerted by PBC and intention on behaviour was explored (Baron and Kenny, 1986). By using SEM, the regression association between psycho-social factors and the dependent outcomes was investigated to understand their relative importance. SEM can be described as a multivariate statistical analysis combining simultaneously a factor analysis and a multiple regression analysis. It is able to test structural relationship between measured variables and latent constructs that cannot be directly observed (e.g. attitude, subjective norm, perceived behavioural control, intention). Indeed, latent constructs can be inferred through the observed variables (i.e. the scores of the questionnaire item) that are used to represent them. On this basis, SEM approach uses a hypothesis testing to analyse the structural theory applied to a certain phenomenon (Byrne, 2010). Parameters associated to observed and latent variables are used in the structural equations (Tarka, 2018). Several indices were used to assess the goodness-of-fit of the model: $\chi 2$/degrees of freedom ($\chi 2$/df), comparative fix index (CFI), Tucker-Lewis Index (TLI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA). Model adequacy and goodness is generally confirmed when $\chi 2/df < 2$, CFI and TLI > 0.95, SRMR and RMSEA < 0.08 (Hu and Bentler, 1999). The explained variance of the dependent (endogenous) variables, such as intention and behaviour, was quantified through the coefficient of Determination (R^2). The Bayesian estimation routine was used to estimate the model in IBM® SPSS® AMOS 24.0, consistently to what recommended in presence of categorical variables (Byrne, 2010).

3.2.3 Results

3.2.3.1 Participant characteristics

The time used to complete the survey was applied as quality control. After removing incomplete and low-quality records, the final sample was composed by 838 respondents, representative of the adult residents in Italy. Participants' characteristics are provided in Table 1. Approximately half of them were females (52%) and most of the respondents were from 35 to 65 years old (80%). The vast majority of the sample reached a secondary education attainment (93%), 53% worked as full time employees and 54% lived in a household without children. Respondents were apparently healthy,

declaring a normal body weight (60%) and physiological conditions (74%), including being in menopause, pregnancy or breastfeeding (9%). Most of the subjects were the in charge of food purchasing and preparation (72% and 63%, respectively), without contingent experience in collaborating or taking part in solidarity purchasing groups (SPGs) or environmental associations (89%). Compared to the Italian population, adults with primary education were less represented, contrarily to those who reached the third education level.

Table 1. Anthropometric variables, demographic characteristics, health conditions and food-related habits of respondents (n=838) and national absolute data (expressed as thousands).

	Sample N (%)	Italian population N (%)
Gender		
Female	434 (51.8)	19,405.3 (50.1)*
Male	404 (48.2)	19,354.2 (49.9)*
Age (y)		
18–24	89 (10.6)	4,158.4 (11.9)§
25–34	157 (18.7)	6,643.6 (19.0)§
35–44	198 (23.6)	8,373.1 (24.0)§
45–54	209 (24.9)	7,849.3 (22.5)§
55–65	185 (22.1)	7,911.9 (22.7)§
BMI (kg/m^2)		
<18.5 (underweight)	36 (4.3)	(3.7)¥
18.5–24.9 (normal weight)	501 (59.8)	(52.5)¥
25.0 –29.9 (overweight)	226 (27.0)	(33.3)¥
30.0 – 34.9 (obesity class I)	57 (6.8)	
35.0 – 39.9 (obesity class II)	15 (1.8)	(10.5)¥
≥ 40 (obesity class III)	3 (0.4)	
Health conditions		
Anaemia/hypertension/dyslipidaemia	83 (9.9)	nf
Food intolerance or allergies	138 (16.5)	nf
Menopause/pregnancy/breastfeeding	73 (8.7)	nf
None of the above	544 (64.9)	nf
Nationality		
Italian	818 (97.6)	5,542.1 (91.7)ǂ
Other	20 (2.4)	5,047.0 (8.3)ǂ
Geographical area of residence		
Nord-West	220 (26.3)	10,185.0 (26.1)*
Nord-East	168 (20.1)	7,396.1 (19.0)*
Centre	167 (19.9)	7,706.7 (19.8)*
South	192 (22.9)	9,305.4 (23.9)*
Islands	91 (10.9)	4,420.6 (11.3)*
Size of residence (number of inhabitants)		
< 5,000	148 (17.7)	9,815.2 (16.3)†
5,000 – 49,999	348 (41.5)	31,731.0 (52.6)#
50,000 – 500,000	206 (24.6)	9,581.8 (15.8)ǂ
> 500,000	136 (16.2)	9,231.5 (15.3)‖

Education		
Primary/lower secondary	62 (7.4)	27,986.0 (49.9)‡
Secondary	448 (53.5)	16,950.9 (30.2)‡
Tertiary (including short cycle tertiary education) or higher	328 (39.1)	6,271.0 (11.2)‡
Occupation		
Full time employee	441 (52.6)	18,551.2 (48.2)§
Part time employee	133 (15.8)	4,299.6 (11.2)§
Unemployed	158 (18.9)	2,528.5 (6.6)§
Retired	35 (4.2)	3,107.9 (8.0)§
Student	71 (8.5)	(13.3)ǂ
Monthly household net income		
< €900	49 (5.9)	1st quintile: 10.1§
€900 – €1,499	144 (17.2)	2nd quintile: 14.5§
€1,500 – €2,499	267 (31.9)	3rd quintile: 19.3§
€2,500 – €3,499	176 (21.0)	4th quintile: 25.7§
€3,500 – €4,499 euro	70 (8.4)	5th quintile: na§
≥ €4,500	48 (5.7)	
Do not wish to tell/do not know	84 (10.0)	
Household types		
Single or living alone	76 (9.1)	nf
Household without child(ren)	450 (53.7)	nf
Household with child(ren)	312 (37.2)	nf
Responsibility in food purchase		
Main responsible	601 (71.7)	nf
Co-responsible	222 (26.5)	nf
Little or not at all responsible	15 (1.8)	nf
Responsibility in meal preparation		
Main responsible	529 (63.1)	nf
Co-responsible	262 (31.3)	nf
Little or not at all responsible	47 (5.6)	nf
Frequency of eating out		
Never or seldom	129 (15.4)	nf
< 1 time/week	167 (19.9)	nf
1 time/week	195 (23.3)	nf
2-4 times/week	249 (29.7)	nf
≥ 5 times/week	98 (11.7)	nf
Taking part to SPGs or EAs		
Yes	93 (11.1)	nf
No	745 (88.9)	nf

Note: * data refer to the population (15-64y) living in Italy in 2018 (Eurostat, 2018); § data refer to the population living in Italy in 2018 (Eurostat, 2018); ¥ data refer to the population living in Italy in 2014 and the value expressed for obesity rate incorporates obesity class I, II, and III (Eurostat, 2014); † data refer to a residence size below 5,000 (Istat, 2019); # data refer to a residence size ranging from 5,000 to 59,999 (Istat, 2019); ǂ data refer to a residence size ranging from 60,000 to 249,999 (Istat, 2019); ‖ data refer to a residence size > 250,000 (Istat, 2019); ‡ data refer to the population living in Italy in 2011 (Istat, census 2011); ß data refer to the population (15-64y) living in Italy in 2019 (Eurostat, 2019); ⸸ data processed from Istat database, 2016; ⸗ data refer to the population (15-64y) living in Italy in 2017 (Istat, 2017); ǂ data refer to the population (18-64 y) living in Italy in 2018 (Eurostat, 2018); EAs: environmental associations; nf: not found; SPGs: solidarity purchasing groups.

3.2.3.2 Participants' conceptualisation about sustainable diet

As shown in Table 2, the low environmental impact and its respect for the biodiversity were the concepts the respondents associated more to the meaning of diet sustainability (selected by 59% of the respondents). A sustainable diet is recognised also as healthy and balanced by 46% of the subjects and as able to sustain and protect the workers in the agricultural sector by 30% of the volunteers. Only 16% of the subjects linked diet sustainability to the consumption of meat. The MD was indicated as sustainable by 24% of respondents, while both vegetarian and vegan dietary patterns were overall not recognised as sustainable diets, as each was selected by less than 3% of the subjects.

Table 2. Percentage of respondents who associated the following concepts to the meaning of sustainable diets. Participants could choose a maximum of three alternative answers.

	Respondents (%)
Diet with a low environmental impact and respectful of biodiversity	58.8
Healthy and balanced diet	46.3
Diet with products whose purchase sustains and protects the workers in the agricultural sector	30.3
Diet based on seasonal foods	29.2
Diet based on local/or traditional products	24.7
Mediterranean diet	23.8
Diet with a limited meat consumption	15.5
Diet based on products with certifications linked to the area and/or method of production	14.8
Economic diet	5.7
Vegetarian diet	2.7
Vegan diet	2.5

3.2.3.3 Descriptive analysis of the TPB constructs and food consumption

Table 3 reports descriptive statistics of the TPB constructs, the factor loadings (λ) between each item and the relative construct, as well as the model fit measures. The mean values obtained for each item show a positive attitude, PBC and intention, with scores ≥ 5.0, indicating a general agreement within the subjects and confirming attitude and PBC as the most positive constructs. Lower intermediate values (< 5.0) have been instead reported for subjective norm, self-identity and self-perceived behaviour. In general, respondents exhibit a positive attitude and relatively strong perceived control over adopting sustainable diet in the next future. Considering the answers to single items, high agreement was expressed by the participants in considering the adoption of a SuDiet as healthy. However, the selection of neutral scores for the items referred

to subjective norm indicated that important reference or peers are not exerting a role by encouraging or showing the adoption of the behaviour of interest to the subjects. The highest score for self-perceived behaviour was reached for the item referred to the consumption of local and or seasonal food, while the self-perception of the adoption of a SuDiet was near the neutrality.

Table 3. Mean and median values of single items representing TPB constructs and model fit indices.

	Mean ± SD	Median (IR)	λ	CR	AVE	α
Attitude	5.8 ± 1.2	6.0 (5.3–6.8)		0.922	0.748	0.923
Adopting a SuDiet is useless/useful	5.9 ± 1.2	6.0 (5.0–7.0)	0.861			
Adopting a SuDiet is unsatisfactory/satisfactory	5.7 ± 1.3	6.0 (5.0–7.0)	0.921			
Adopting a SuDiet is unhealthy/healthy	6.1 ± 1.2	6.0 (6.0–7.0)	0.801			
Adopting a SuDiet is unpleasant/pleasant	5.5 ± 1.4	6.0 (5.0–7.0)	0.872			
Subjective norm	4.3 ± 1.2	4.3 (3.5–5.0)		0.872	0.630	0.869
Most people important to me think I should adopt a SuDiet	4.0 ± 1.5	4.0 (3.0–5.0)	0.771			
Most people I esteem would approve my adoption of a SuDiet	4.6 ± 1.5	5.0 (4.0–6.0)	0.779			
Most people I respect will adopt a SuDiet	4.3 ± 1.4	4.0 (4.0–5.0)	0.862			
Most people like me have adopt a SuDiet	4.1 ± 1.5	4.0 (3.0–5.0)	0.758			
Perceived behavioural control	5.2 ± 1.1	5.3 (4.5–6.0)		0.841	0.641	0.870
I believe I am able to adopt a SuDiet	5.1 ± 1.3	5.0 (4.0–6.0)	0.938			
If I wanted to, I could adopt a SuDiet	5.4 ± 1.3	5.0 (5.0–6.0)	0.763			
My adoption of a SuDiet is under my control	5.3 ± 1.3	5.0 (5.0–6.0)	0.680			
Self-identity				-	-	-
I think to myself as a person interested to diet sustainability	5.0 ± 1.4	5.0 (4.0–6.0)	-			
Intention	5.1 ± 1.4	5.0 (4.3–6.0)		0.967	0.879	0.968
I intend to adopt a SuDiet in the next future	5.1 ± 1.4	5.0 (4.0–6.0)	0.933			
I want to adopt a SuDiet in the next future	5.1 ± 1.4	5.0 (4.0–6.0)	0.929			
I will adopt a SuDiet in the next future	5.1 ± 1.5	5.0 (4.0–6.0)	0.945			
I plan to adopt a SuDiet in the next future	5.0 ± 1.5	5.0 (4.0–6.0)	0.943			
Self-perceived behaviour	4.4 ± 1.4	4.7 (3.7–5.3)		0.836	0.632	0.833
I can say I have adopted a SuDiet within the last 3 months	4.0 ± 1.7	4.0 (3.0–5.0)	0.876			
I can say I have limited the consumption of animal-based products within the last 3 months	4.4 ± 1.7	5.0 (3.0–5.8)	0.811			
I can say I have mostly consumed local and/or seasonal foods within the last 3 months	4.7 ± 1.4	5.0 (4.0–6.0)	0.687			
Behaviour				-	-	-
Adherence to MD score (on a 0-9 scale)	4.0 ± 1.7	4.0 (3.0–5.0)	-			

Note: CR: composite reliability; AVE: average variance extracted; α: Cronbach's α; λ: factor loadings represented by unstandardized regression weights. Both mean ± SD and median (IR) are indicated due to the non-normality in data distribution.

The results from the CFA applied to TPB constructs and their antecedents show very good item reliability and convergent validity, with factor loadings (λ), CR values, AVE values and Cronbach's α falling respectively in the range 0.68 – 0.95, 0.63 – 0.88, 0.84 – 0.97, and 0.83 – 0.97, all above the relative recommended thresholds

(Table 3). Psychometric analysis of TPB constructs indicated that the measures utilized in the present study were fully reliable and Cronbach's alpha coefficients indicated that all scales had satisfactory internal reliability (Nunnally, 1978).

Self-reported behaviour measured as adherence to MD, scored on a 0-9 range, provided a picture of respondents based on food group consumption frequency showing a medium compliance to this dietary pattern. When considering the consumption frequency of single food items (Table 4), 59% and 69% of respondents were eating respectively one portion of fruit and vegetables or less. Similarly, 61% and 55% of respondents stated to consume less than one portion of wholegrain pasta or rice, and bread or substitutes, respectively, with approximately 20% of the whole sample never or hardy never eating wholegrain products. In less than 10% of the subjects a consumption of red meat exceeding 3 portions per week was higher than the amount covered by the Mediterranean dietary pattern. More than 50% of people stated instead to consume from 1 to 3 portions a week of red and white meat.

Table 4. Percentage distribution of respondents according to their consumption frequency of single food groups/items.

	Percentage of respondents (N= 838)				
Food groups	Never or seldom	<1/day	1/day	2/day	≥3/day
Wholegrain pasta or rice	19.2	42.2	33.4	4.1	1.1
Vegetables, all types	8.7	26.9	33.3	28.9	3.1
Fruit, all types fresh and fresh juices	7.2	25.4	26.1	32.5	8.8
Milk and yoghurt	19.9	30.0	36.9	11.2	2.0
	Never or seldom	<1/day	1-2/day	3-4/day	≥5/day
Wholegrain bread and substitutes	22.0	33.1	39.9	4.4	0.7
Olive oil to cook and to dress	4.2	22.8	59.8	11.5	1.8
Butter, margarine or cooking cream	58.4	32.5	7.2	1.4	0.6
Wine	48.3	30.8	17.3	2.9	0.7
	Never or seldom	<1/week	1-3/week	4-6/week	≥7/week
Red meat, meat products	11.7	27.7	51.2	8.1	1.3
White meat	9.1	28.3	56.9	4.9	0.8
Carbonated and/or SSB	43.3	27.8	21.5	4.5	2.9
Sweets	23.5	37.4	24.0	10.1	5.0
	Never or seldom	<1/week	1/week	2-3/week	≥4/week
Fish or sea foods	9.7	28.9	28.8	30.2	2.5
Nuts	30.2	26.1	14.7	19.2	9.8
Pulses	12.5	30.4	28.6	25.7	2.7

The categories of consumption frequencies are expressed as number of portions per day or week. SSB: sugar-sweetened beverages.

With regards to fish and sea food products, respondents were equally distributed among those who consumed less than one, one, and two-three portion(s) per week, with approximately 30% of people falling in each of these three categories. Furthermore, 72% of the respondents consumed no more than 1 portion per week of legumes, below the amount recommended by the Mediterranean dietary model. The majority of subjects reported also a low or very low intake of soft drinks (71%) and sweets (61%).

Table 5 shows the descriptive statistics of behavioural, normative and control beliefs. On average, the most important outcome of adopting a SuDiet is the positive impact on health that received the highest composite mean score, followed by the positive effect on environment.

Table 5. Behavioural, normative and control beliefs.

Behavioural beliefs	(b)	(e)	(b) * (e)
Positive impact on health	1.5 ± 1.1	1.9 ± 0.9	3.4 ± 2.9
Positive effect on environment	1.6 ± 1.1	1.7 ± 1.0	3.3 ± 2.7
Adoption of a ethical behaviour	1.4 ± 1.1	1.6 ± 1.0	2.9 ± 2.6
Satisfaction from a sensory perspective	1.1 ± 1.2	1.5 ± 1.0	2.1 ± 2.5
Food habits modification	1.1 ± 1.2	0.8 ± 1.3	1.4 ± 2.5
Improvement of culinary skills	0.9 ± 1.2	1.2 ± 1.1	1.8 ± 2.5
Support to local economy	1.3 ± 1.1	1.3 ± 1.0	2.4 ± 2.6
Support to small/medium size farmers	1.3 ± 1.1	1.4 ± 1.0	2.5 ± 2.6
Normative (injunctive) beliefs	(i_n)	(m)	(i_n) * (m)
Partner	0.2 ± 1.6	4.9 ± 1.8	2.4 ± 8.1
Family	0.1 ± 1.6	4.6 ± 1.5	1.6 ± 7.6
Dear friends	- 0.9 ± 1.5	4.1 ± 1.6	0.7 ± 6.8
Doctors/nutritionists/experts	0.6 ± 1.6	4.9 ± 1.3	3.4 ± 8.0
Institutions	0.1 ± 1.6	4.2 ± 1.5	1.5 ± 7.1
Normative (descriptive) beliefs	(d_n)	(m)	(d_n) * (m)
Partner	0.5 ± 1.6	4.9 ± 1.8	3.7 ± 8.2
Family	0.4 ± 1.6	4.6 ± 1.5	2.7 ± 7.7
Dear friends	0.1 ± 1.5	4.1 ± 1.6	1.3 ± 6.4
Control beliefs	(c)	(p)	(c) * (p)
Informative labels on the products	5.2 ± 1.0	1.4 ± 1.1	7.9 ± 6.1
Price reduction	4.7 ± 1.3	1.4 ± 1.1	7.2 ± 5.8
Free time available	4.5 ± 1.3	1.0 ± 1.2	4.9 ± 6.0
Not being alone	4.7 ± 1.2	1.0 ± 1.2	5.4 ± 6.1
Food variety in collective catering	5.0 ± 1.2	1.3 ± 1.0	7.3 ± 6.2

Note: Data are expressed as mean ± SD. (b): behavioural belief strength converted to bipolar scale (-3; +3); (c): control belief strength; (d_n): descriptive belief strength; (e): outcome evaluation converted to bipolar scale (-3; +3); (i_n): injunctive belief strength converted to bipolar scale (-3; +3); (m): motivation to comply; (p): power of control factor.

The lowest mean scores, but still positive, can be instead observed in relation to food habits modification and improvement of culinary skills. Notably, the low composite score referred to food habit changing is mainly due to its outcome evaluation (e) showing that for several consumers this outcome was not desirable. On the contrary, the low composite score associated to the improvement of culinary skills can be explained by the fact that according to subjects the adoption of a SuDiet quite unlikely will trigger this outcome.

Respondents were not or slightly interested in knowing if friends or institutions think they should adopt a SuDiet. On the contrary, the opinion that doctors, nutritionists or experts may express was the most considered. Nevertheless, from the obtained results, social pressure was overall weakly perceived. The possibility to dispose of more informative food labels and a wide variety of food products in collective catering, as well as reduced food prices, were indicated as the main factors that could favour the behaviour performance.

3.2.3.4 Correlation and comparative analysis

As shown in Table 6, all the constructs included in the TPB or extended TPB model (i.e. with self-identity) are significantly correlated between each other ($\rho < 0.01$). The highest correlations coefficients can be observed between self-identity and intention ($\rho = 0.81$) and PBC ($\rho = 0.72$), which is in turn highly correlated with intention ($\rho = 0.77$). These data are compliant with the expectations showing that the respondents who were more willing to adopt a SuDiet were those who perceived to have more control on behaviour performance and who perceived themselves as people interested in the topic. Intermediate correlation levels ($0.52 < \rho < 0.67$) reported for the association between TPB variables and behaviour as self-perceived by the subjects indicate that who already perceived to perform the behaviour were more likely to have more positive opinions on it, more control and stronger intention to adopt a SuDiet in the next future. On the other hand, no correlation can be observed between the TPB constructs and the behaviour as measured by the adherence to MD. This is likely due to the different measurement scale used to assess the TPB constructs and the MD adherence score. In addition, self-identity was significantly correlated to all the TPB constructs including self-perceived behaviour and adherence to MD (respectively 0.66, 0.39, all at $p<0.01$). A weak negative linear correlation was instead detected between

BMI and attitude (ρ = -0.11, p<0.01), PBC (ρ = -0.15, p<0.01), intention (ρ = -0.18, p<0.01), and SP-behaviour (ρ = -0.17, p<0.01). According to the non-parametric applied tests, the scores of the TPB constructs significantly differed when the participants were grouped based on socio-demographic or other dichotomous, multinomial or ordinal variables. Thus, the applied statistics cannot infer on correlation between variables, but suggests that respondents who fell in different groups for each of these variables answered differently when ask for tick the boxes referred to TPB constructs. No statistical differences were found when respondents were grouped for nationality and geographical area of residence.

Table 6. Correlations and comparisons between TPB constructs and measured variables.

	Attitude	SN	PBC	Intention	SP-Behaviour	Behaviour
TPB constructs						
Attitude [§]	1.00	0.49**	0.61**	0.68**	0.52**	0.32**
SN [§]	-	1.00	0.51**	0.59**	0.49**	0.27**
PBC [§]	-	-	1.00	0.77**	0.54**	0.35**
Intention [§]	-	-	-	1.00	0.67**	0.36**
SP-Behaviour [§]	-	-	-	-	1.00	0.39**
Other constructs						
Self-identity [§]	0.63**	0.54**	0.72**	0.81**	0.64**	0.39**
Socio-demographics						
Gender [¥]	***	ns	ns	ns	ns	***
Age [#]	**	*	ns	ns	*	ns
Family composition	ns	*	ns	ns	ns	ns
Residence size [#]	ns	*	ns	ns	ns	ns
Educational level [#]	ns	*	**	*	*	*
Occupation [#]	ns	**	ns	ns	*	ns
Income [#]	ns	**	*	*	*	*
Other variables						
BMI [§]	-0.11**	ns	-0.15**	-0.18**	-0.17**	0.20**
Health conditions [#]	*	*	ns	**	**	ns
Resp. in food purchase [#]	***	***	***	***	***	***
Resp. in food preparation	***	***	***	***	***	***
Coll. with SPGs or EAs [¥]	**	***	ns	***	***	**
Eating out frequency [#]	ns	*	ns	ns	ns	ns

Note: [§] Spearman's rank-order correlation (ρ) between attitude, subjective norm, PBC, intention, self-perceived behaviour and adherence to MD (indicated as "Behaviour") and socio-demographic, and other health- or habit-related variables. [¥] p values associated to the comparison between TPB constructs and dichotomous variables, Mann-Whitney non parametric test; [#] p values associated to the comparison between TPB constructs and multinomial or ordinal variables, Kruskal Wallis non-parametric test. Significant correlations or differences are indicated with *, **, ***, respectively at 95% level (p<0.05), 99% level (p<0.01), 99.9% level (p<0.001); age groups were defined as: 18–24, 25-34, 35-44, 45-54, 55-65; ns = not significant. EAs: environmental associations; SPGs: solidarity purchasing groups.

Table 7 shows the correlations between salient beliefs and (i) their relative direct measures, (ii) intention, and (iii) behaviour. This investigation is relevant to build effective interventions addressed to behavioural change by targeting the beliefs significantly associated to the latent variable that is the most important in predicting intention. In the present study, the most important predictor of intention is PBC, followed by attitude (Table 8). Consistently with this path, the results suggest that the accessibility to more exhaustive labels and having the possibility to adopt the behaviour with other people are significantly correlated ($p < 0.01$, $\rho = 0.50$ and $\rho = 0.45$, respectively) with intention. These control beliefs were also correlated with PBC, self-perceived behaviour and adherence to MD.

Table 7. Spearman's rank order correlations (ρ) between salient beliefs and their relative direct measure (attitude, subjective norm and PBC), intention, self-perceived behaviour and adherence to MD.

Behavioural beliefs	Attitude	Intention	SP-Behaviour	Behaviour
Positive impact on health	0.477	0.469	0.384	0.261
Positive effect on environment	0.500	0.485	0.368	0.250
Adoption of a ethical behaviour	0.514	0.482	0.366	0.244
Satisfaction from a sensory perspective	0.555	0.500	0.391	0.244
Food habits modification	0.388	0.329	0.319	0.182
Improvement of culinary skills	0.407	0.364	0.329	0.191
Support to local economy	0.498	0.444	0.424	0.245
Support to small/medium size farmers	0.507	0.481	0.421	0.262
Normative (injunctive) beliefs	Subjective norm	Intention	SP-Behaviour	Behaviour
Partner	0.582	0.472	0.350	0.210
Family	0.608	0.465	0.373	0.229
Dear friends	0.597	0.384	0.330	0.168
Doctors/nutritionists/experts	0.541	0.426	0.304	0.157
Institutions	0.524	0.364	0.294	0.160
Normative (descriptive) beliefs	Subjective norm	Intention	SP-Behaviour	Behaviour
Partner	0.604	0.541	0.389	0.257
Family	0.657	0.558	0.461	0.283
Dear friends	0.634	0.463	0.403	0.249
Control beliefs	PBC	Intention	SP-Behaviour	Behaviour
Informative labels on the products	0.482	0.501	0.425	0.294
Price reduction	0.359	0.376	0.363	0.201
Free time available	0.321	0.367	0.373	0.217
Not being alone	0.345	0.389	0.360	0.190
Food variety in collective catering	0.418	0.449	0.365	0.203

Note: all the correlations are significant at $p<0.001$.

The further regression paths represented by attitude and subjective norm on intention were statistically significant, suggesting that targeting the relative beliefs can be of help in raising the intention to adopt a sustainable food consumption behaviour, even if in principle less effective than addressing to control dimension. Compared to behavioural and normative injunctive beliefs, normative descriptive beliefs show statistically significant correlation with intention (ρ ranging from 0.46 to 0.56). In particular, the family behaviour instead of its opinion is strongly correlated to intention suggesting to have a more impacting role in predicting the participants' adoption of a SuDiet. Among the behavioural beliefs, the sensorial satisfaction was correlated to intention (≥ 0.50, $p < 0.01$), highlighting this outcome as particularly relevant in driving the behavioural intention. Among the correlations between the beliefs and the relative direct measures, normative dimension reached the highest correlation coefficients ranging from 0.52 to 0.66. On the other hand, the lowest coefficients were found for the behavioural control dimension (0.32 – 0.48).

3.2.3.5 SEM analysis

Table 8 reports the two best fitting SEMs relating TPB constructs to intention and self-perceived behaviour (Model 1) and adherence to MD (Model 2). Both Model 1 and 2 explain 78% of the variance in intention to adopt a SuDiet, while different results were observed in the explained behaviour variance, respectively accounting for 54% and 13%. The TPB constructs are all significant contributors ($p < 0.001$) to intention in both models, with PBC showing the highest standardised weight regression coefficients (ß: 0.57, Model 1 and ß: 0.58, Model 2). The significant constructs predicting behaviour are intention (0.19, $p < 0.01$) and PBC (0.18, $p < 0.05$) in Model 2 and only intention (0.70, $p < 0.001$) in Model 1. Table 8 shows also the measures of model adequacy, indicating an optimal fitting with values within the suggested thresholds for all the indices. Positive unstandardized weight regression coefficients (B) indicated to what extend the adoption of behaviour (as self-perceived or measured in terms of adherence to MD) increased when the scores for the relative TPB constructs go up by 1 unit (e.g. if intention went up by 1 unit, the adoption of a SuDiet, as perceived by the subjects, increases by 0.76 units in the applied scale).

Using AMOS Bayesian module, SEM coefficients between different behaviours and the relative TPB drivers, intention and PBC were estimated. The behaviours were measured as frequencies of consumption of different food groups, e.g. fruits,

vegetables, legumes, red meat. The results, displayed in Table 9, showed the unstandardized weights connecting the TPB drivers (intention and PBC) with the behaviour as estimated by 15 different models. A value of B = 0.18 in the second column, indicated that when intention went up by 1 unit, the frequency of consumption of fruit went up by 0.18 in the relative scale. This increase was significant with p = 0.004. On the contrary, a B value of -0.22 and -0.13 indicated the extend by which the red meat and sweet beverages intake frequency went down when intention went up by 1 unit. These reductions are statistically significant ($p < 0.001$ and $p = 0.03$, respectively). Fruit, vegetables and legumes were the food groups with the highest explained variance of frequency of consumption with a value of 8%. Intention was the most important predictor for the consumption of all the food groups, with the exception of fish, legumes, olive oil and wholegrain bread for which PBC was more relevant (B = 0.22, B = 0.12, B = 0.10, and B = 0.10, respectively). However, B values were not always associated with significant p values ($p < 0.05$), as shown by legumes ($p = 0.06$) and wholegrain bread ($p = 0.082$).

Table 8. SEM relating attitude, subjective norms and PBC to intention and self-perceived behaviour and MD adherence.

Paths	B	SE	ß	R^2	χ^2	DF	TLI	CFI	RMSEA	SRMR
TPB Model 1 (a)					399.16***	121	0.974	0.979	0.052 (0.047 – 0,058)	0.033
Attitude → Intention	0.252***	0.037	0.210							
SN → Intention	0.233***	0.037	0.214	0.779						
PBC → Intention	0.592***	0.047	0.568							
Intention → SP-Behaviour	0.761***	0.070	0.669	0.543						
PBC → SP-Behaviour	0.094	0.073	0.079							
TPB Model 2 (a)					240.63***	91	0.983	0.987	0.044 (0.038 – 0.051)	0.026
Attitude → Intention	0.247***	0.037	0.206							
SN → Intention	0.227***	0.037	0.207	0.778						
PBC → Intention	0.603***	0.048	0.576							
Intention → Behaviour	0.262**	0.097	0.193	0.130						
PBC → Behaviour	0.258*	0.104	0.182							

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; B: unstandardized weight regression coefficients, ß: standardised weight regression coefficients; SE: standard error; DF: degree of freedom; SN: subjective norm; R^2: explained variance.

Table 9. Unstandardized coefficients (B) and standard error (SE) of intention and PBC as predictors of the consumption frequency of single food groups, and R^2.

	Intention		PBC		R^2
	B	SE	B	SE	
Wholegrain pasta or rice	-0.019	0.051	0.073	0.054	0.007
Wholegrain bread and substitutes	0.007	0.052	0.099	0.057	0.021
Pulses	0.118	0.062	0.124	0.066	0.076
Milk and yoghurt	0.049	0.059	0.095	0.063	0.030
White meat	-0.118**	0.045	0.065	0.048	0.015
Red meat, meat products	-0.217***	0.048	0.070	0.052	0.062
Fish or sea foods	-0.058	0.064	0.224***	0.070	0.043
Vegetables, all types	0.146**	0.055	0.086	0.058	0.079
Fruit, all types fresh and fresh juices	0.178**	0.062	0.080	0.066	0.083
Nuts	0.155	0.081	0.137	0.087	0.067
Olive oil to cook and to dress	0.009	0.044	0.100*	0.048	0.031
Butter, margarine or cooking cream	-0.039	0.044	0.030	0.047	0.001
Carbonated and/or SSB	-0.128*	0.060	-0.003	0.062	0.026
Sweets	-0.034	0.064	-0.038	0.068	0.006
Wine	0.020	0.051	-0.031	0.055	0.001

By adding self-identity as further predictor of intention and behaviour in our models, the explained variance of those endogenous variables reached lower values (72% for intention; 44% and 10% respectively for self-perceived behaviour and MD adherence score) and reduced model fitting measures (data not shown).

Three self-identity groups (Low SI, Medium SI and High SI) were defined based on tertiles of the self-identity index score, resulting in nearly similar group sizes (see also van Bree *et al*., 2013; Menozzi, Sogari, and Mora, 2017). Thus, low self-identity was defined as lower than or equal to 4 (n = 245), medium self-identity as scored 5 (n = 300) and high self-identity as equal or higher than 6 (n = 293). Table 10 displays the median values for all the TPB constructs divided by SI groups and for the total sample. From comparison of the three groups significant statistical differences were found in the median of all the TPB variables.

Table 10. TPB constructs values referred to low, medium and high self-identity (SI) groups and to total sample.

	Low SI (N=245)	Medium SI (N=300)	High SI (N=293)	Total (N=838)
Attitude	5.0 (4.0 - 5.8)	6.0 (5.5 - 5.6)	6.5 (5.8 - 7.0)	6.0 (5.3 - 6.8)
SN	3.5 (2.5 - 4.0)	4.5 (4.0 - 4.8)	4.5 (4.0 - 5.3)	4.3 (3.5 - 5.0)
PBC	4.3 (3.8 - 5.0)	5.3 (4.8 - 4.8)	5.8 (5.0 - 6.3)	5.3 (4.5 - 6.0)
Intention	4.0 (3.0 - 4.3)	5.0 (4.8 - 5.5)	5.8 (5.0 - 6.5)	5.0 (4.3 - 6.0)
Behaviour	3.0 (2.0 - 4.0)	4.0 (3.0 - 5.0)	4.0 (3.0 - 6.0)	4.0 (3.0 - 5.0)
SP-Behaviour	3.3 (2.3 - 4.0)	4.7 (3.7 - 5.0)	5.0 (4.3 - 5.7)	4.7 (3.7 - 5.3)

Note: data are expressed as median (IR). Comparison between Low, Medium and High Self Identity groups and TPB constructs, non-parametric Kruskal Wallis test for independent samples. All differences of the construct scores among the self-identity groups were significant at $p<0.001$.

Multi-group SEM was used to test for differences of the model determinants across the three SI groups. Model 2 (a) resulted less effective in explaining the variance in intention (54-60%) and behaviour (20-24%) compared to the total sample (Model 1 (a), Figure 1). However, the predictors of intention changed when the groups were individually considered. Subjective norm is more important in Low SI group, implying these people were prone to be more influenced by other (ß: 0.50, $p<0.001$). On the other hand, PBC is higher in the Medium (ß: 0.51, $p < 0.001$) and High SI (ß: 0.68, $p < 0.001$) groups, suggesting they perceived to have a higher control on the adoption of a SuDiet in the next future. Furthermore, the role of attitude was more relevant in Low SI (ß: 0.21, $p < 0.001$) than Medium (ß: 0.11, $p < 0.10$) or High SI (ß: 0.13, $p < 0.05$) meaning that who perceived his/herself as less interested in diet sustainability but had a positive opinion of it, then he/she will have a higher intention to adopt a SuDiet. In

each group, the only significant predictor of self-perceived behaviour was intention, with the lowest regression coefficients found in the High SI group. Thus who is already more interested in food sustainability issues, a change of behavioural intention is less impacting on behaviour as self-perceived.

Table 11. SEM Multi-group analysis showing unstandardized regression coefficients, standard error and model fit measures.

	Low SI		Medium SI		High SI		Model fit					
Paths	B	SE	B	SE	B	SE	χ^2	DF	TLI	CFI	RMSEA	SRMR
TPB Model 2 (a)							698.52	363	0.947	0.958	0.033 (0.030-0.037)	0.057
Attitude → Intention	0.192 ***	0.055	0.100	0.054	0.160 *	0.079						
SN → Intention	0.558 ***	0.091	0.252 ***	0.063	0.056	0.032						
PBC → Intention	0.143 **	0.053	0.439 ***	0.092	0.580 ***	0.088						
Intention → SP-Behaviour	0.310 ***	0.065	0.478 ***	0.108	0.421 **	0.144						
PBC → SP-Behaviour	-0.006	0.028	0.002	0.084	0.148	0.127						
TPB Model 2 (b)							444.77	273	0.968	0.976	0.027 (0.23 -0.32)	0.047
Attitude → Intention	0.190 ***	0.055	0.093	0.055	0.169 *	0.078						
SN → Intention	0.553 ***	0.091	0.236 ***	0.063	0.061	0.031						
PBC → Intention	0.149 **	0.054	0.470 ***	0.095	0.564 ***	0.087						
Intention → Behaviour	0.004	0.099	0.008	0.244	0.700 *	0.292						
PBC → Behaviour	0.078	0.059	0.359	0.238	-0.074	0.257						

Note: *, **, *** significant values at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively. B: unstandardized weight regression coefficients; DF: degree of freedom; SE: standard error.

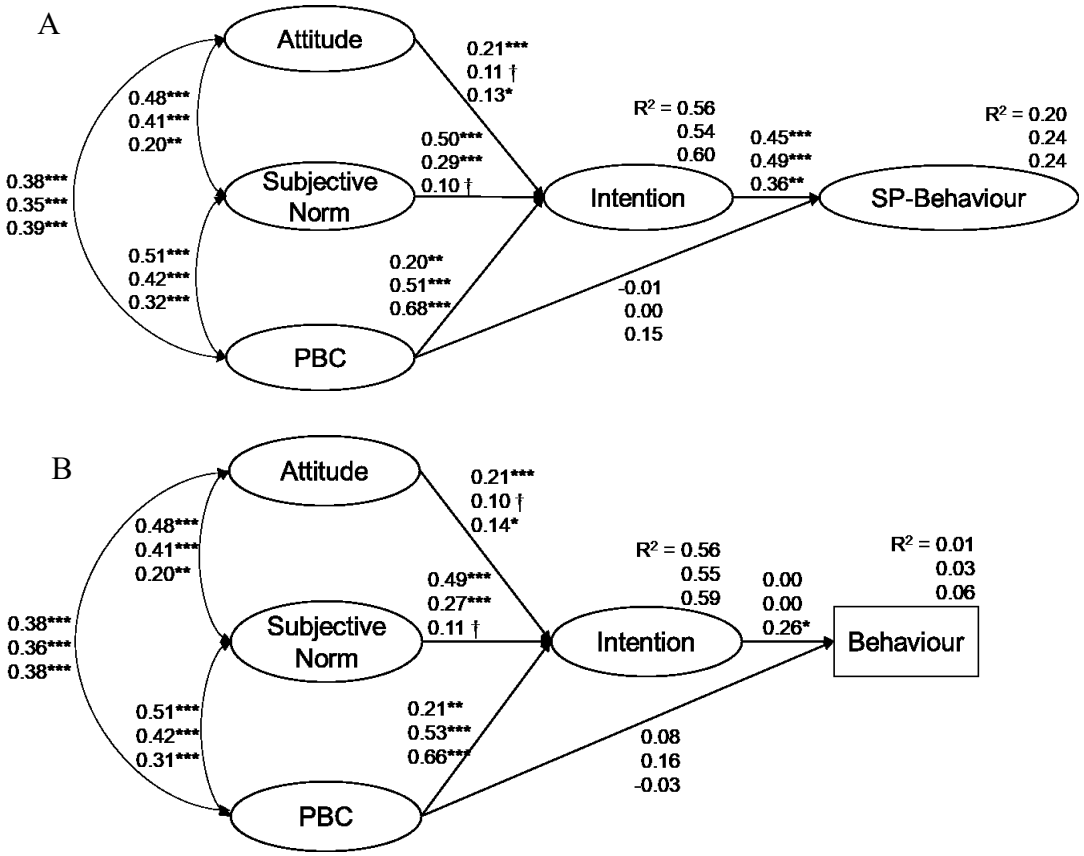

Figure 1: Multi-group SEM analysis – standardised regression coefficients and R-squared for endogenous variables in Model 2 (A) and Model 2 (B). Upper values indicate standardised regression weights for low self-identity group, middle values for medium self-identity group, and bottom values for high self-identity group. Signif. codes: *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$, † = $p < 0.10$.

Multi-group SEM analyses on MD adherence showed that Model 2 (b) explained a similar variance in intention (55-59%) compared to Model 2 (a), but exhibited a very low ability in explaining behaviour variance (1-6%). The predictors of intention differed in the three SI groups, similarly to Model 2 (a). The intention was able to impact the behaviour only in the high SI group arguing that a higher intention reflected a better adherence to MD only in the respondents more interested in food sustainability.

Both the multi-group structural equation models fit data very well, with better values compared to those obtained for one group structural equation models, providing the rational to use self-identity as moderator and obtain a better insight on the collected data.

3.2.4 Discussion

This research applied a cross-sectional study design to understand the drivers and barriers able to affect the adoption of a SuDiet by an adult population, to explain the behavioural intention and predict behaviour. The TPB was used as theoretical framework to build the survey in which an exhaustive definition of SuDiets was provided, compliant with FAO's statement (Burlingame and Dernini, 2012). Due to its complexity, a more explicit definition was indicated to provide the respondents with a unique interpretation. Single and multi-group structural SEM models were applied to investigate the most important paths explaining intention and predicting behaviour. Two behavioural measures were used. The first measure reflected the behaviour adoption as perceived by the respondents who were asked to score three items on a 7-point Likert scale, while the second was a score of adherence to MD, based on the self-reported single food group consumption frequency (Gnagnarella *et al*., 2018).

Attitude, subjective norm and PBC accounted together for 78% of the variance in intention, while 54% of self-perceived behaviour variance was predicted by intention and 13% of adherence to MD was explained by intention and PBC. These results confirmed previous evidence according to which the TPB better explains self-reported behavioural measures compared to more objective measures of behaviour (Armitage and Conner, 2001; McEachan *et al*., 2011). Findings suggest that PBC plays a significant role in determining the intention to follow a SuDiet. In other words, the higher is the perceived ability to adopt a SuDiet, the higher is the intention to actually adopt it. However, even if to a lesser extent, also attitude and subjective norm significantly contributed to form intention, meaning that the personal and important others' positive evaluation of the behaviour had a direct impact on respondents' intention. These results are common to other studies showing PBC as the most important predictor of intention compared to attitude and subjective norm (Close *et al*., 2018; Lin 2013; Masalu and Åstrøm, 2001; Russell *et al*., 2017). Contrarily, other researchers found attitude to primarily form intention, with a lower contribution expressed by PBC and subjective norm (Hagger *et al*., 2007; Karpinski and Milliner, 2016; Mondéjar-Jiménez *et al*., 2016; Pawlak, Malinauskas, and Rivera, 2009), which is more commonly a weaker predictor of intention (Fishbein and Ajzen 2010; Armitage and Conner, 2001), with higher predictive ability in adolescent samples (McEachan *et al*., 2011). The prediction of perceived behaviour was primarily affected by intention,

while PBC acted as significant contributor only when the adherence to MD was used as dependent variable.

In the present study, the discrepancy between self-perceived behaviour and the results obtained from the food frequency questionnaire might be explained by different reasons. First, there is a non-complete overlapping between the behaviour as described by the items used to assess it as self-perceived and its actual (even though self-reported) performance. Secondly, as previously described, three-fourth of the respondents did not promptly recognise MD as a sustainable dietary pattern, meaning that most of the subjects had an erroneous perception of it. Furthermore, the subjects could have even adopted a sustainable dietary pattern, but different from that represented by MD.

As already stated in the literature (Fishbein and Ajzen, 2010; Armitage and Conner, 2001), one motivation of the low explained variance obtained when MD was applied as final dependent variable may be related to the principle of compatibility (i.e. the same action, target, context, and time elements should correspond to TPB constructs and the behaviour of interest), which is less strict in this specific framework. Moreover, the self-perceived behaviour assessment applies the same scale of measurement of the TPB constructs, i.e. from 1 to 7, maximising the measurement correspondence (Armitage and Conner, 2001). Contrarily, the measurement of more objective (self-reported) behaviour was based on a score from 0 to 9 to determine the degree of adherence to MD, or on a score from 1 to 5 to evaluate the frequency of consumption of single food groups. The consideration of additional variables in the model, such as the degree of perception of MD as sustainable diet, might increase the explained variance in behaviour, when adherence to MD was applied as final dependent variable.

When the consumption frequency of single food groups was evaluated, most of the respondents were not found compliant with national dietary recommendations, as shown by their fruit and vegetable intake being far below the suggested cut-off (Research Centre for Food and Nutrition, 2003).

As expected, when the consumption of single food groups was applied to the model, negative statistical regression coefficients were observed for red and white meat, sweet beverages and desserts, implying that when intention increases by 1 unit, the frequency of consumption of such products decreases, to the highest extent for red

meat (-0.22) and to the lowest for desserts (-0.03). Nevertheless, the strongest negative association between the consumption of red meat and the adoption of a sustainable diet, such as the MD, does not seem to be consciously perceived by the respondents. Indeed, when they were asked to select three dietary patterns perceived as more sustainable (choosing from a list of eleven), only 16% of the respondents picked a diet characterised by a limited consumption of meat.

The moderating role of self-identity was assessed by splitting the total sample in three different groups based on tertiles of self-identity index score. This way, different paths emerged highlighting the role of social norms in the respondents less interested in food sustainability. The present study did not confirm previous evidence according to which self-identity explained additional variance in behavioural intention and/or behaviour when it was added to the TPB model as an additional independent variable (Hagger and Chatzisarantis, 2006; Armitage, Conner, and Norman, 1999). However, considering self-identity as moderating variable (Fishbein and Ajzen, 2010), interesting results were obtained, with self-identity basically measuring how much a consumer is interested in food sustainability. Therefore, this variable can be considered as analogous to the attitude towards the behaviour, suggesting the subject's positive or negative propensity towards enacting the behaviour of interest. However, self-identity also refers to the normative component, implying that if the respondents identify themselves as consumers more interested in the topic then they are more likely to follow a SuDiet compared to their counterparts. This line of reasoning might explain why people who are already more interested in food sustainability are less influenced by third parties in defining their intention to follow a sustainable diet. In addition, more interested people also felt they had higher control on behaviour, as supported by the fact that the interest strength is more correlated with PBC, and the intention variance in these people is more strictly influenced by changes in PBC.

The TPB postulates that interventions aiming at modifying behavioural, normative, or control beliefs may succeed in producing the desired changes in behaviour by affecting behavioural intention, attitudes, subjective norms, and perceptions of control. In other words, interventions designed at promoting sustainable dietary behaviours should target the beliefs mostly correlated with those constructs able to make the behaviour more likely to occur. The present study highlighted some intervention strategies that should be targeted to improve the individuals' perceived

control over the behaviour, namely including more information on the product labels, increasing the food variety in collective catering, and reducing the price of sustainable food products. To address these points, indications about the geographical origin and/or the environmental impact associated to the production phase, including the processing and the means of transportation used along the supply chain can be listed as options. Furthermore, in collective catering more plant-based options should be offered providing indications on how to build nutritionally balanced menus, combining the products served on a daily basis. As pointed by several studies on price change effects on dietary behaviour, subsidies aimed at reducing the price of healthful foods (e.g. fruits and vegetables) are effective tools in increasing their consumption (Afshin *et al*., 2017). Given the average low score of subjective norm items, targeting the components linked to the social influence on individual's behaviour was instead hypothesised to be a less effective strategy. Among these items, the one referred to doctors/nutritionists/ experts obtained a relatively higher score, thus the opinion of such professionals and public institutions campaigns could improve the public awareness about these themes. The support to local communities and to small and medium producers, and the sensory property of food products, are among the main beliefs able to affect intentions as well as self-perceived and actual behaviour, if properly communicated by informative campaigns.

3.2.5 Strengths and limitations

To the best of our knowledge, this is the first study in which the TPB was applied as a framework to investigate the role of behavioural precursors in explaining the intention to follow a sustainable diet, as well as its adoption by the adult population. Several studies have been performed applying TPB on diet-related behaviour, however most of them only considered discretionary food choices (e.g. increasing fruit and vegetable intake, limiting sugar-sweetened beverages, etc.), or specific nutritional aspects (e.g. follow a low-fat diet). In addition, the investigation of sustainable food behaviour was mostly addressed to evaluate single sustainability dimensions simultaneously (e.g. follow a healthy diet; consume organic food), failing to approach the complexity of diet sustainability. Indeed, this study tried to encompass different sustainability dimensions, as expressed in the items used to represent the TPB constructs. The study is limited, however, by the nature of the tool applied to assess dietary behaviour. Indeed, the applied self-administered questionnaire may fail to

accurately record actual food intake when compared to the food diary, which is the gold standard instrument to assess this outcome and the reference method commonly used to validate other dietary assessment intake methods (Illner *et al*., 2012). Furthermore, the behaviour was not prospectively assessed and although this shortcoming is common in several similar studies, it prevents the opportunity to investigate potential behavioural changes over time, as well as possible modifications in the relationships between behaviour and its predictors. Finally, it is worth mentioning that, in the present study, the measurement of the concurrent behaviour compared to its longitudinal assessment limits the compatibility principle based on time elements between the TPB constructs and the behaviour itself. Indeed, the TPB constructs refer to the adoption of a SuDiet in the next future, while the behaviour is cross-sectionally measured.

3.2.6 Conclusion

The present research tested the TPB model's ability to predict the adoption of a SuDiet and the factors affecting this behaviour in a representative sample of adults residing in Italy. The dietary behaviour was assessed as self-perceived, and more objectively as degree of adherence to the Mediterranean dietary pattern, intended as a proxy of sustainable food consumption. The TPB model effectively explained from 54% to 78% of variance in the intention to adopt a SuDiet in the next future and showed its behavioural predicting ability with a different efficacy when self-perceived behaviour or MD adherence score/single food group consumption were entered in the model, with TPB constructs accounting respectively for 20-54% and 0-13% of the explained variance. By applying self-identity as moderator of intention-behaviour relationship, the measures of model fit improved, however the explained variance did not. Overall, the sample reported a medium adherence to MD, a widely recognised model of dietary sustainability and rooted in the Italian culture. The obtained results confirm the gradual shift away from this dietary pattern and support the need to address efforts in driving dietary transition and develop intervention strategies tailored to adults as target population. Interventions mainly directed at increasing awareness about food and diet sustainability issues, improving attitude and fostering the perceived control on food consumption at individual level are recommended.

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Study 3

Nutritional, environmental, and economic impact of children's school lunch plate waste: a comparison between two Italian case studies

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Abstract

Background. Food waste quantification, analysis and monitoring in collective catering constitute important efforts to minimise nutritional, environmental and economic shortcomings.

Scope and approach. The present study aimed at comparing two Italian case studies (Parma *vs.* Lucca) in relation to the impact of primary school children's plate waste. A multi-target approach was applied to evaluate nutritional, environmental and economic implications. The investigation was performed in 4 primary schools where, across 10 days each, an aggregate selective weighting method was applied to collect plate waste into 7 food categories. On this basis, nutritional and economic losses, as well as the embodied carbon footprint were analysed. In addition, a 5-point Likert scale was applied to assess vegetable liking.

Key findings and conclusions. The median plate waste percentage was lower in Parma (24.6 (IR: 21.8–27.3) than in Lucca 41.4 (IR: 33.2–42.6), $p < 0.001$). In both cases, vegetables were the most wasted food group, but more disliked in Lucca, followed by fruit and bread, with median percentages ranging from 26.2 (IR:15.8–40.0) to 55.5 (IR: 41.8–59.3). Conversely, protein-based and (semi)unique dishes were the least wasted. However, (semi)unique plates and starchy food accounting for 72% of the global carbon impact in Parma. Overall, after adjusting for plate waste data, most of the lunch menus fell below the national energy and nutrient recommendations. Plate waste accounted for 5% (Parma) and 14% (Lucca) of the full price per meal paid by families. A re-planning of the school meals service organisation and priorities is needed to decrease the inefficiency of the current system and to reduce food waste and its consequent nutritional, environmental and economic losses.

Key words: plate waste, school lunch, nutritional adequacy, carbon footprint, economic impact

3.3.1 Introduction

Ensuring sustainable consumption and production patterns by 2030 is the number twelve of sustainable development goals promoted by the 193 UN Member States (UN, 2019). A call for a global reduction, by 50%, of the food waste both at the distribution and at the consumer level has been launched. In parallel, a limitation of food losses at the production level as well as along the supply chain has been recommended (Target 12.3) by addressing substantial efforts to prevention, reduction, recycling and reuse activities (Target 12.5). In this framework, the public procurement sector is directly implicated in the promotion of sustainable practices, consistently with the national policies and priorities (Target 12.7) (UN, 2019). The food procurement in school settings has the primary aim of providing students with meals having adequate energy and nutrient contents to support their physical growth and development, school performance, and lay the foundations for healthy and balanced dietary habits in the adulthood (Oostindjer *et al*., 2017). At school, primary school children spend a long-time and consume at least one meal every day. Thus, the school environment is an ideal setting to support healthy dietary behaviours. In this framework, school food procurement represents a major target to reduce the risk of inadequate dietary intakes that are risk factors for morbidity and mortality worldwide (Afshin *et al*., 2019).

Several countries have developed national nutritional guidelines for primary school meals. The sustainability is in focus such as in Italy, where the public administration targets the improvement of school catering service sustainability by designing healthy and balanced meals, according to the recommendations of the Research Centre for Food and Nutrition (CRA-NUT), and promoting organic and locally sourced products (Ministero della Salute, 2010). Recommendations about food waste are also included. However, several factors may influence the actual children's dietary intake in the context of institutionalised meals, such as in the school setting. Of these, the criteria established by food procurement policies can be mentioned as upstream factors, while, more directly, the following aspects can play an important role: the food facilities, including the opportunity to prepare and cook school lunches on site, the canteen's ambient (Cordingley, Reeve, and Stephenson, 2011); the presence of children's supervisors in the canteen eating with children (Martins *et al*., 2016). Moreover, numerous determinants able to affect the plate waste in primary school-aged children have been reported. The list includes dietary habits (Liu *et al*.,

2016; Falasconi *et al*., 2015); limited knowledge about the food supply chain (Liu *et al*., 2016); availability of alternative food items (Marlette, Templeton, and Panemangalore, 2005); children's dissatisfactions about the offered food mainly in terms of food appearance and taste (Huang *et al*., 2017); menu composition (Falasconi *et al*., 2015); a default offer of fruit and/or vegetables (Just and Price, 2013); energy requirement and portion size with regard to the children's age (Niaki *et al*., 2017); limited time to eat (Cohen *et al*., 2016); lunch timing before recess, when children are less hungry (Murray and Ramstetter, 2013).

Food loss and waste, estimated to be approximately 1.3 billion tons per year corresponding to approximately one third of the food which is produced for human consumption (Gustavsson *et al*., 2011), has direct and indirect effects on environment leading to consequences on natural resources at global level, including water depletion, and climate change (Jan *et al*., 2013). Food waste is responsible for economic costs and additional use of land, water, chemicals and energy that could be mitigated by enhancing virtuous management practices and strategies to prevent it (Storup *et al*., 2016). Furthermore, when generated in a school context, beyond the environmental perspective, food waste exerts a nutritional impact due to the gap between the food which is planned to be consumed by children and their actual intake. To address this issue, food waste quantification, analysis and monitoring in collective catering constitute important efforts to address waste minimisation (Tostivint *et al*., 2016). Furthermore, because of the huge number of users and the consequent amount of food handled every day, the school meal service represents an appropriate sector of intervention to address the educational aim of increasing awareness in young generations on food sustainability issues (FAO, 2019). Plate waste, intended as the amount or percentage of served food that people discard, could serve as a marker to estimate food intake and the efficacy of interventions designed to improve healthy eating behaviour at schools (Ishdorj *et al*., 2015; Niaki *et al*., 2017).

The research activities described in the present study address the issue of plate waste in a primary school context from a nutritional, environmental and economic perspective. The study, carried out within the framework of the Strength2food European Project (https://www.strength2food.eu/), seeks to investigate and compare two Italian case studies (municipalities of Parma *vs.* Lucca), characterised by two different food procurement models (local-organic, LOC-ORG *vs.* organic, ORG) in

relation to: (i) the nutritive values of selected daily lunch menus, as planned by the catering service; (ii) children's food waste; (iii) children's liking (and refusal) towards the vegetable side dish; (iv) the nutritional, (v) environmental and (vi) economic impact caused by children's plate waste.

3.3.2 Materials and methods

3.3.2.1 Case study description

The LOC-ORG case model is applied in 33 primary schools in Parma municipality (Emilia Romagna region, North Italy) having a pupil roll above 200 and an average meal uptake of 90%. All schools offer lunch meals carefully designed and approved by municipal dieticians, with a full price to parents of € 6.18 per day. School menu is defined on a four week-cycle distinguished across the four seasons. Menus typically include a daily single-option meal composed by a starchy-based first course (e.g. pasta, rice), a protein-based second course (e.g. eggs, meat, fish, legumes), side vegetables, bread, and fruit. After the first course, the second and the side dishes are served together with bread. Dessert is served only on special occasions, such as before holidays. Occasionally, first and second courses are substituted by unique dish containing both starchy-based and protein-based products (Comune di Parma, 2019). A private catering firm prepares and cooks the meals off-site in a cooking centre and then transports them to the majority of the schools (n=25) located within the municipality. The unique exception is represented by starchy-based dishes, which are prepared directly on-site. In the remaining schools (n=8) all the ingredients are delivered directly and cook on-site, in the internal kitchen. The staffing levels equate to 5-6 kitchen personnel per school, depending on numbers of meals served. The cater, which is part of a large enterprise, subcontracts food procurement to 29 suppliers (mostly large-scale enterprises), ten of which are the most relevant. Although the public sector food procurement (PSFP) contract in LOC-ORG case encourages local sourcing, the definition of "local food" is broad. Indeed, based on regional guidelines (Regione Emilia- Romagna, 2009), school meal provision should be mainly constituted by "local products" (supplied within the Province), "zero km products" (supplied at a maximum distance of 100 km from the city centre), and "short chain products" (produced within the adjacent provinces). However, the description of a minimum threshold is lacking. The regional guidelines specify instead a minimum amount of organically grown products, EU certified quality and traditional products

(e.g. PDO and PGI), or food coming from integrated production. In total, the sum of these products should be at least 70% of all foods employed for meal preparation (Regione Emilia-Romagna, 2009). Furthermore, since 2009, the City Council, the University of Parma and some private firms promoted an educational program ("Giocampus") aimed at fostering the wellbeing of future generations through physical activity and nutritional education in all Parma primary schools. A figure called "Maestro del Gusto" (literally "Master of Taste") uses a ''learning through playing'' teaching technique to encourage healthy eating habits and food sustainability (Rosi *et al*., 2016).

The ORG case model is applied in 29 primary schools in Lucca municipality (Tuscany region, Centre Italy), having an average pupil roll below 100 and average meal uptake of 89%. All schools offer lunch meals designed and approved by municipal dieticians with a full price to parents of € 5.00 per day. The lunch menu runs on seven/eight weeks-cycle and is differentiated in two seasonal periods (i.e. autumn-winter and spring-summer). The structure of the menus is the same of LOC-ORG case, although dessert is served more frequently, as a substitute of fruit. A private catering firm prepares and cooks all the meals in a central kitchen from which they are transported to school sites where only cereals-based dishes (e.g. pasta and stock soups) can be assembled with sauce or other dressing. The staffing levels equate to 3-4 staff per school. The caterer, which is part of a regional corporate enterprise, subcontracts to 9 suppliers, which constitute large enterprises and approximately half of the suppliers are located within Tuscany region. School meal provision is mainly characterised by organic products, followed by other EU certified products (e.g. PDO and PGI) and short food supply chain products (Regione Toscana, 2010).

3.3.2.2 School selection

Four primary school canteens were selected, two in Parma and two in Lucca, representing respectively a LOC-ORG and a ORG model. To take into account the internal heterogeneity of the two case studies and to allow a meaningful comparison between them, the school selection was driven by the following criteria: a minimum number of 100 pupils attending the schools; the presence of a distinct meal preparation and delivering model (e.g. food prepared and distributed from central or internal kitchen). Alternatively, if a unique meal-delivering model was present, different distances between the schools and the cooking centre were considered. The profile of

the selected schools is provided in Table 1. For all the children from 6 to 11 years who had lunch in the selected schools, the school time ranged from 8.30 a.m. to 4.30 p.m. and lunch was served to pupils divided into turns starting from 12.00 a.m. or 12.30 a.m., with each children group having 25-30 minutes to eat.

Table 1. Profile of the selected schools in the LOC-ORG and ORG case model.

Schools	City	Meal-delivering model	Distance from the cooking centre	Pupils (n) [a]	Meal uptake (%)
LOC-ORG_1	Parma	Internal (on-site kitchen)	n.a.	215	90
LOC-ORG_2	Parma	External (off-site kitchen)	16.7 km	239	95
ORG_1	Lucca	External (off-site kitchen)	8.2 km	168	90
ORG_2	Lucca	External (off-site kitchen)	3.7 km	212	88

Note: [a] number of children who signed up for the school lunch service; the distance from the cooking centre for LOC-ORG_1 school is not applicable as the school lunches are prepared on site; n.a.: not applicable.

3.3.2.3 Data collection

Annual school lunch menus were obtained from the City Council web sites or directly from school Officers of the Council Operative Unit for School catering services. Normative provisions (i.e. the standard quantities of ingredients and recipes) were instead obtained from local managers of the central school catering services. Five consecutive days (from Monday to Friday) in winter 2017 and spring 2018 were randomly selected in each school, for a total of 40 daily menus. Only standard meals were considered, with the exclusion of special diets. A plate waste data collection was organised in each of the chosen days, with one exception in the ORG case study, for a total of 39 days of collection activities. Plate waste, intended as the uneaten edible fraction of food served to children, was collected from all the children in the four primary school canteens applying a modified aggregate selective plate waste method (Comstock *et al*., 1979). Plate waste was collected as separated in seven food categories, i.e. starchy foods; bread; protein-based dishes (meat, fish, diary, legumes); vegetables served as side dish; fruits; desserts; and "other" which included semi-unique and unique dishes. Each food category was collected in separate bins, collecting all the food items used as ingredients in the preparation of the plates assigned to each specific food category (e.g. the tomato sauce used to dress pasta was collected as plate waste and scraped together with pasta in the same bin). Fruit category was included in

the data collection, as served at the end of the lunch in one of the two selected schools in Lucca. In all the remaining schools it was served at mid-morning, to be eaten as a snack.

The procedure used to assess the plate waste was a direct weighing method (namely aggregate selective plate waste) according to which food waste was collected from all the children, but separately for each of the seven defined food categories. The direct weighting method is considered the gold standard (Boschini *et al*., 2018) as empirically reliable and minimising disruption in the school canteen, as well as human, financial and time resources (Comstock *et al*., 1979). First, the average weight of the edible food served to children was calculated from 3 randomly chosen portions per turn. As pupils always eat separated into two turns, the calculation was based on 6 random portions of offered edible food. Both the average portion and the food waste were assessed using electronic weighting scales.

To assess children liking of the vegetable served as side dish, a questionnaire reporting a 5-point Likert scale (from 1=I dislike it to 5=I like it a lot) was administered to the pupils during the same days (Wardle *et al*., 2003). The questionnaire was administered after lunch in the school canteens, otherwise in classroom immediately after lunch. The questionnaire was filled in presence of at least one researcher or a teacher who could provide further explanations for the completion. In addition to the liking score, the children indicated if they ate all the portion of vegetables that was offered to them and recorded their grade and sex.

3.3.2.4 Data analysis

3.3.2.4.1 Nutritional analysis

For each recipe of the school menus, energy and nutritive values per portion planned to be served were calculated using national composition database for epidemiological studies in Italy provided by the European Institute of Oncology (IEO) (Gnagnarella, Salvini & Parpinel, 2008). If not available in the national database, where possible, energy and nutritive values were obtained from the food labels. The nutritional composition of the offered meals was evaluated with regard to national guidelines for school lunch considering both energy and nutrient intakes, as well as the food consumption frequency (Table 2). The energy and nutrient contents of each food item were summed at a daily basis to obtain the energy and nutritional profile of

each school lunch menu and average values were calculated across the full data collection period. By subtracting the energy and nutrient content of wasted food to those calculated for the meals planned to be served, an estimation of the actual energy and nutrient intakes was provided.

Table 2. National recommendations for energy and nutrients content of lunch provided by schools to children aged 6-11, as well as recommended frequency of intake for each food group to be served during the school lunch.

Lunch meal component	Range or value
Energy (kcal) (35% of daily energy)	520-810
Proteins (g) (10-15% of the meal energy)	13-30
Animal-Plant Proteins Ratio	0.66
Fats (g) (30% of the meal energy)	18-27
of which saturated fat (g)	6-9
CHO (g) (55-60% of the meal energy)	75-120
of which sugars (g)	13-30
Iron (mg)	6
Calcium (mg)	350
Fibre (g)	6
Food Group	**Frequency of intake**
Fruit	One serving every day
Vegetables	One serving every day
Cereals (e.g. pasta, rice, barley, corn)	One serving every day
Bread	One serving every day
Legumes	Once or twice a week
Potatoes	No more than once a week
Meat	Once or twice a week
Fish	Once or twice a week
Eggs	Once a week
Cheese	Once a week
Ham and cured meat	Twice a month
(Semi)unique dish (e.g. pizza, lasagne)	Once a week

3.3.2.4.2 Plate waste analysis

The total food waste (kg) was obtained as the sum of the food waste (kg) collected across all food categories, for the two schools of each case study, and across both data collection weeks. Accordingly, the total served food (kg) has been calculated as the sum of the served food for each food category for the two schools of each case study, across both data collection weeks. The served food (g) corresponds to the average portion of edible served food (g) multiplied by the number of the served meals. The percentage of food waste for each food category has been obtained as the ratio between the total edible plate waste (kg) referred to each food category, and the total amount of each food category (kg) served to the children. Finally, the total food waste (g) and

the food waste of each food category (g) has been divided by the number of served meals to estimate the waste per meal (g). By subtracting this ratio to the average portion of edible served food, the food intake per child was estimated.

3.3.2.4.3 Environmental analysis

The environmental impact of food waste was estimated in terms of GHG emissions associated with the food production and food waste management by the school meal services in the two case studies. The applied emissions factors (EFs) origin from the scientific literature (Tregear *et al*., 2019), BCFN Double Pyramid database (BCFN, 2016), the Environmental Product Declaration (EPD) database (EPD International AB, 2019), LCA-Food database (Nielsen and Rikke, 2007), and Ecoinvent database (Ecoinvent, 2019). Specifically, the EFs for the food waste refer to the approach proposed by Moult and colleagues (Moult *et al*., 2018). The emissions calculated by food category took into account the ingredients used for preparing the meals, i.e. the food items having contributed to the food waste for each food category. Differently to the estimation of the nutritional impact of food waste, the estimation of the environmental impact referred to a sample of five schools per each case study. Three schools in each municipality were randomly selected and added to the ones already considered for the plate data collection. In addition, the amount of embodied carbon attributed to plate waste was estimated for the scholar year aggregating data on plate waste recorded during the data collection period. Therefore, the environmental analysis was based on a total plate waste higher than the one used in the nutritional analysis. The waste rates of individual food items within each food category were estimated either via direct observation by the food waste collector, when possible, and/or by inspecting the relevant ratios of the food procurement data. First, the food items included in each category defined for plate waste were qualitatively and quantitatively determined. An average EF per kg of each food category was then calculated by dividing the total production emissions (kg CO_2eq) due to all the food items under each wasted food category by the total volumes (kg) of those items procured across the five schools for each case. In this way, the average EF for each food category took into account the varying proportions of specific food items within the waste category, and their specific EFs. Next, by multiplying the average EF for each food category by the total volumes of waste recorded for those food categories in each case, the total production-related embodied carbon emissions for each food

category were estimated. The same method was followed to calculate the transport-related embodied carbon emissions for each food category. Finally, the embodied carbon emissions related to the waste transportation and disposal were added. The three component of the embodied carbon emissions (i.e. production, transportation and waste disposal) were then summed to get the total embodied carbon emissions of the collected plate waste in each case. It is worth mentioning that in both case studies, food waste is managed following the composting system applied by the municipalities.

3.3.2.4.4 Economic analysis

To estimate the financial loss associated with the collected plate waste, an average cost per kg of each waste per food category was computed by dividing the total supply budget related to each category by the volumes of specific items procured within that category, in proportion to each other. Therefore, the average costs per kg reflected the varying volumes of different food items procured within each category, and their specific costs. Specifically, estimation of average cost per kg for each food waste category was made through the market price of each food item retrieved form the statistics provided by the national Institute of Agri-food Market Services (ISMEA). The total cost of waste for each food category was then summed to derive an estimate of the total cost of plate waste for the two cases.

3.3.2.4.5 Statistical analysis

Descriptive and inferential statistics were applied. Data are expressed as mean ± standard deviation (SD) or as median (interquartile range) for continuous variables or as frequencies/percentages for categorical variables. The normality of data distribution was explored using the Kolmogorov-Smirnov test. According to data distribution comparisons between the two groups (LOC-ORG *vs*. ORG) were tested using the Student's t-test or the Mann-Whitney U test. Furthermore, the Chi-square (χ^2) test was used for exploring associations between categorical variables. The statistical analysis was performed using SPSS 25.0 software (SPSS Inc., Chicago, IL, USA), keeping the significance at $p < 0.05$.

3.3.3 Results

3.3.3.1 Nutritional composition of menus

As shown in Table 3, energy and nutrient contents of the average school lunch meals were similar between the two case studies, except for vitamin C, potassium, phosphorous and iron levels that were higher in the menus of the LOC-ORG model.

Table 3. Average energy and nutritive value of school lunches (n=20) per PSFP model.

	LOC-ORG	ORG
Energy (kcal)	705.5 ± 91.4	691.6 ± 71.7
Macronutrients		
Proteins (g)	30.5 ± 5.9	27.2 ± 4.8
Carbohydrates (g)	104.1 ± 12.1	103.0 ± 13.1
Soluble sugars (g)	22.6 ± 6.5	22.6 ± 8.2
Fats (g)	20.4 ± 7.2	21.0 ± 4.5
SFA (g)	7.0 ± 6.4	5.8 ± 3.1
Cholesterol (mg)	49.8 ± 34.4	67.4 ± 56.4
Dietary fibre (g)	12.9 ± 3.5	10.1 ± 4.6
Vitamins		
A (µg RE)	31.8 (19.5 - 102.9)	56.5 (13.9 - 132.2)
B_1 (mg)	0.5 (0.4 - 0.6)	0.5 (0.4 - 0.6)
B_2 (mg)	0.4 (0.3 - 0.5)	0.4 (0.3 - 0.4)
B_3 (mg)	4.5 (3.7 - 6.8)	5.2 (4.0 - 6.8)
B_6 (mg)	0.7 (0.6 - 0.8)	0.8 (0.6 - 0.9)
B_9 (µg)	108.7 (92.1 - 142.7)	101.6 (70.2 - 121.0)
B_{12} (µg)	1.3 (0.4 - 1.6)	1.3 (1.0 - 1.8)
C (mg)	82.0 (56.9 - 106.3)	50.1 (23.7 - 75.2)**
D (µg)	0.2 (0.1 - 0.4)	0.2 (0.2 - 0.9)
Minerals		
Sodium (mg)	585.6 (506.9 -768.9)	521.3 (451.2 - 864.5)
Potassium (g)	1.3 (1.1 – 1.4)	1.0 (0.8 – 1.3)*
Calcium (mg)	279.7 (261.2 - 321.6)	260.9 (198.1 - 354.9)
Magnesium (mg)	42.9 (26.0 - 63.6)	32.5 (29.9 - 56.3)
Phosphorous (mg)	482.0 (440.2 - 543.7)	417.4 (378.0 - 476.8)**
Iron (mg)	4.8 (4.3 - 5.9)	3.9 (3.6 - 4.6)*
Zinc (mg)	3.4 (2.6 - 3.8)	3.1 (2.8 - 3.9)
Copper (mg)	0.3 (0.1 - 0.5)	0.2 (0.1 - 0.7)

Note: results are expressed as mean ± SD or median (IR). *p* values refer to between group comparison (LOC-ORG *vs*. ORG), Mann-Whitney non-parametric test. *, ** significant differences at $p < 0.05$ and $p < 0.01$, respectively. SFA: saturated fatty acids.

In terms of total energy, according to the Health Ministry, a school lunch should provide 35% of a child's daily energy requirements, i.e. from 520 to 810 kcal (Table 2). Almost all the planned menus (90%) fell within the recommended ranges for both LOC-ORG and ORG case models (Figure 1, A). Regarding the macronutrient

distribution (Figure 1, B), the average protein content of the lunches accounted for 17% and 16% of the total energy provided respectively by the LOC-ORG and ORG model. These percentages are slightly higher than the 10-15% range indicated by the national recommendations. The energy percentage provided by carbohydrates was instead on average compliant with the standards, accounting for no more than 60% of total energy in both case studies. On the other hand, the selected school lunch menus were no adequate in fat amount that accounted for less than 30% of the lunch energy content in both cases.

In addition, the LOC-ORG model resulted more frequently above the value recommended in the national guidelines compared to ORG model for carbohydrates (15% *vs.* 10%), soluble sugars (20 % *vs.* 15%), proteins (60% *vs.* 35%), saturated fatty acids (20% *vs.* 15%), and iron (20% *v*s. 5%) (Figure 1, C, D, F, H, I). For both case studies, the better compliance of the selected school lunches with the Health Ministry guidelines was observed for total carbohydrates, soluble sugars and fats, with percentages ranging from 60% to 90% (Figure 1, C, D and G). In contrast, more than 50% of the menus did not met the standards in terms of saturated fatty acids (Figure 1, I). Indeed, no more than 10% of a child's lunch energy meal intake should be provided by saturated fat and only 10% and 30% of the analysed menus for the LOC-ORG and ORG models, respectively, were found to meet the national standards for saturated fat. However, 70% and 55% of the menus respectively in the LOC-ORG and ORG model, albeit below the values indicated in the Italian guidelines for school catering service, met the National Recommended Energy and Nutrient Intake Levels (SINU, 2014), as well as the dietary reference value for fats provided by European Food Safety Authority (EFSA). The dietary fibre content of the selected menus was above the cut-off indicated by the Health Ministry (6 g) in all the LOC-ORG menus and in 80% of ORG menus (Figure 1, E), whereas in terms of micronutrient (i.e. iron and calcium), the majority of the menus were below the standards in both case studies (Figure 1, I and L).

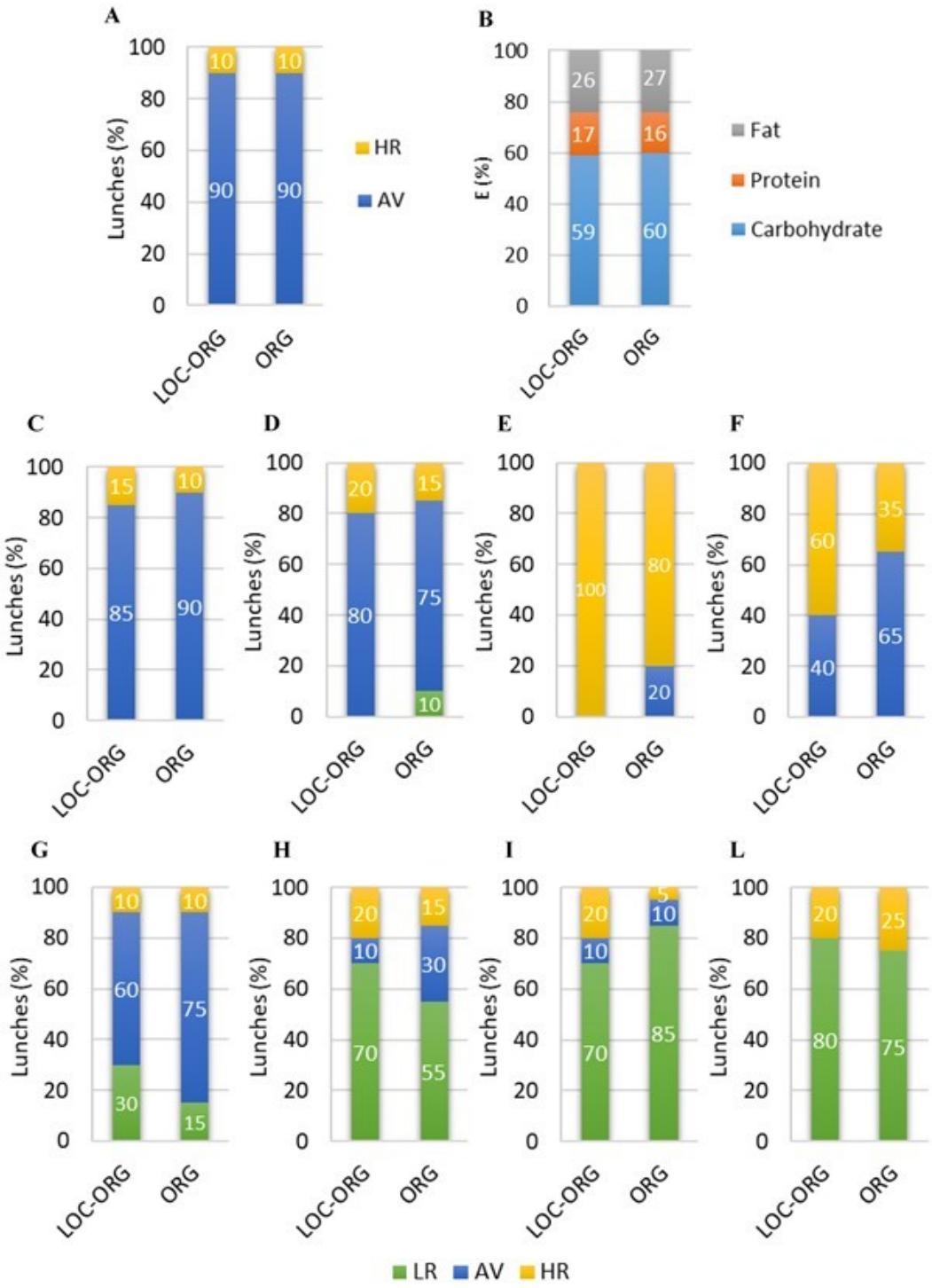

Figure 1. Distribution of school lunches (n=20) by PSFP model according to National recommendation referred to energy (A), carbohydrates (C), soluble sugars (D), dietary fibre (E), proteins (F), fats (G), saturated fatty acids (H), iron (I), and calcium (L). Average percentage of energy provided by total protein, fat and carbohydrate content (B) of school lunches (n=20) per PSFP. AV: adequate value; HR: higher than recommendation; LP: lower than recommendation.

3.3.3.2 Plate waste

The total amount of food waste collected across the two schools and seasons showed a difference of approximately 11 kg between the case studies (541 kg in the LOC-ORG model *vs.* 552 kg in the ORG model, Table 4). However, despite this relative small difference in terms of absolute values, the obtained percentage of total food waste were different between the two case studies ($p < 0.001$), corresponding to a median of 25% (IR: 22 – 27) for LOC-ORG model and of 41% (IR: 33 – 43) for ORG model (Table 5). Distinguishing by food category, the highest and the lowest amounts (kg) of food waste in the LOC-ORG model corresponded respectively to the fruit (164 kg) and to the "other" food (23 kg). This discrepancy is mainly due by the fact that the unique dish considered in this latter category – represented by cous cous with extra-virgin olive oil and beef stewed with green beans and carrots - was served just during one day in spring in both schools (n=2). Conversely, the lowest amount was recorded for the "other" category (3.3 kg) represented by pizza, a semi-unique dish. Similarly to what already mentioned for the LOC-ORG model, the different representation of these two categories in the selected menus explains the discrepancy in the absolute plate waste values (i.e. the first course was served every day, while pizza was served only in 2 occasions). The estimation of daily plate waste is approximately 27 kg for the LOC-ORG and 29 kg for the ORG model. As shown in Table 4, the maximum amount of food waste registered for the ORG model was the starchy food (191.5 kg).

Table 4. Total meals, total servings and total waste reported by food categories per PSFP model (n=20 days).

	Total meals(n)		Total served food (kg)		Total waste (kg)	
	Loc-Org	Org	Loc-Org	Org	Loc-Org	Org
Bread	3988	2677	144.0	81.7	53.6	34.1
Starchy food	3526	3331	813.2	603.4	162.6	191.5
Protein- based dish	3471	2523	223.4	176.2	39.5	60.2
Vegetable - side dish	3979	1453	267.9	131.1	98.7	68.1
Fruit	4134	2304	539.3	338.8	163.6	180.8
Other	387	311	115.5	28.2	22.6	3.3
Dessert	-	690	-	76.7	-	13.7
All food categories	19485	13289	2103.2	1436.2	540.6	551.9

Comparing the two case studies, the serving size of each food category is comparable with the exception of fruit, which was higher in the ORG model (Table 5). The food waste percentages were significantly lower in the LOC-ORG model for all food categories ($p < 0.01$), with the unique exception of bread that was similar between the two case studies ($p = 0.149$) (Table 5). Similarly, waste per meal values (in grams) of starchy food ($p < 0.05$), protein-based dish ($p < 0.01$) and fruit ($p < 0.01$) were significantly higher in the ORG model. Although data expressed as total values were comparable between the two cases considering the serving size, the waste percentage and the waste per meal were significantly lower in the LOC-ORG model compared to the counterpart ($p < 0.01$ for both).

When considering the comparison between different food categories within the case studies a strong heterogeneity in relation to the plate waste and waste per meal was observed. In both cases, the starchy food and fruit showed the largest absolute amounts of plate waste (kg). For the LOC-ORG case study, the greatest waste percentage (about 35%) was reported for bread followed by vegetables, while the lowest (about 15%) refers to the protein based – dish. The waste per meal, ranging from a median of 9 g (IR: 5 – 16) for the protein-based dish to 59 g (IR: 53 – 66), for the "other" category, reflects a different serving size (g) offered to pupils. In the ORG case, fruit and vegetables exceed 50% of plate waste, while the semi-unique dishes that were the least wasted (12%). Therefore, the pupils' uptake of plant – based food (i.e. fruit and vegetables) was less than the half of the average portion served to the pupils, while in the LOC-ORG model it was approximately 65%. Beyond these findings, we observed different trends of waste among meals belonging to the same category (data not shown). Simple recipes (e.g. pasta or rice dressed with olive oil) seemed to be wasted to a lesser extent if compared with more elaborate recipes (e.g. gnocchi with tomato sauce). Nevertheless, due to the limited number of observations, it is not possible to derive definitive indications from these results.

Table 5. Serving size, waste percentage and waste per meal expressed as total daily values and by food categories for case study 1 (LOC-ORG) and 2 (ORG).

	Portion size (g)		Waste (%)		Waste per meal (g)	
	LOC-ORG	ORG	LOC-ORG	ORG	LOC-ORG	ORG
Bread	40.6 (25.3–48.5)	30.2 (26.3–32.3)	35.7 (32.5–40.5)	44.8 (35.3–53.5)	11.3 (8.8–18.1)	12.3 (9.8 –15.1)
Starchy food	240.9 (194.7–265.4)	211.0 (192.5–225.9)	16.5 (13.5–24.7)	32.5 (25.3–40.2)**	40.1 (28.1–64.7)	64.9 (45.4 –85.9)*
Protein dish	55.7 (40.0–93.0)	60.8 (51.3–76.3)	14.5 (12.4–18.1)	33.5 (22.1–43.3)**	9.4 (5.1–15.9)	19.1 (13.5–35.5)**
Vegetables	52.9 (43.9–86.1)	57.5 (50.2–78.2)	34.9 (32.0–50.7)	52.9 (41.5–70.1)**	24.3 (20.8–31.3)	28.5 (23.4–44.7)
Fruit	125.9 (120.0–133.9)	151.8 (128.0–175.0)*	26.2 (15.8–40.0)	55.5 (41.8–59.3)**	32.9 (20.5–51.2)	75.4 (50.4–105.5)**
Other	293.7 (261.0–326.4)	93.0 (80.6–105.4)	22.3 (17.7–27.0)	11.8 (11.3–12.3)	59.4 (53.0–65.8)	10.7 (9.7–11.7)
Dessert	-	100.0 (100.0–125.0)	-	14.9 (13.2–19.0)	-	14.9 (13.2–23.8)
Total	506.0 (460.5–599.2)	498.6 (456.3–520.5)	24.6 (21.8–27.3)	41.4 (33.2–42.6)***	139.5 (110.6–155.4)	196.2 (163.5–223.7)***

Note: data are presented as median (IR) given the non-normal distributions. *p* values refer to between group comparison (LOC-ORG *vs.* ORG), Mann-Whitney non-parametric test. Statistical analysis was not performed on the categories "Other" and "Dessert" due to the lack (or the limited number of) data. *, **, *** significant differences at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

3.3.3.2 Vegetable liking expressed by children

When children were asked to express their preferences towards vegetables, a percentage of 18% and 38% in the LOC-ORG and ORG model, respectively, responded "I dislike it" (Figure 2). A percentage of 34% in the LOC-ORG and 25% in the ORG model indicated "I like it a lot", suggesting that pupils in the LOC-ORG model appreciated this food category more than in the counterpart. Higher proportions of children selected the extremes of the Likert scale polarising the obtained scores.

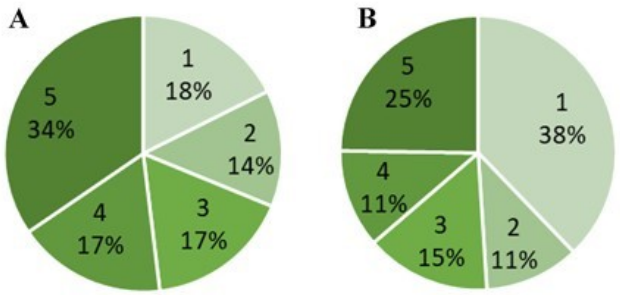

Figure 2. Vegetable rate preferences expressed by children in LOC-ORG (A) and ORG model (B) (1 = "I dislike it", 5 = "I like it a lot").

Tables 6 and 7 report the associations between the liking categories and the nominal variables represented by gender, grade and refusal rate (i.e. the "Yes" group refers to the children who did not eat all the vegetables that were offered to them; "No" group refers instead to those who consumed all the vegetable portion).

Table 6. Children distribution by gender, grade, and refusal by liking categories referred to the LOC-ORG model.

	Total children (n=3957)	Score 1 (n=696)	Score 2 (n=539)	Score 3 (n=668)	Score 4 (n=686)	Score 5 (n=1368)	
Gender							***
Female	2032 (51.4)	336 (8.5)	312 (7.9)	370 (9.4)	372 (9.4)	642 (16.2)	
Male	1925 (48.6)	360 (9.1)	227 (5.7)	298 (7.5)	314 (7.9)	726 (18.3)	
Grade							***
1	785 (19.8)	138 (3.5)	99 (2.5)	83 (2.1)	96 (2.4)	369 (9.3)	
2	791 (20.0)	79 (2.0)	109 (2.8)	95 (2.4)	176 (4.4)	332 (8.4)	
3	812 (20.5)	152 (3.8)	138 (3.5)	164 (4.1)	134 (3.4)	224 (5.7)	
4	765 (19.3)	141 (3.6)	102 (2.6)	168 (4.2)	119 (3.0)	235 (5.9)	
5	804 (20.3)	186 (4.7)	91 (2.3)	158 (4.0)	161 (4.1)	208 (5.3)	
Refusal							***
Yes	2493 (63.0)	696 (17.6)	539 (13.6)	668 (16.9)	516 (13.0)	74 (1.9)	
No	1464 (37.0)	0 (0.0)	0 (0.0)	0 (0.0)	170 (4.3)	1294 (32.7)	

Note: data are presented as pure numbers (% of the total sample). A Pearson chi-square test was used to test the association of all categorical variables with liking groups. *** significant difference at $p < 0.001$.

Table 7. Children distribution by gender, grade and refusal by liking categories referred to the ORG model.

	Total children (n=1733)	Score 1 (n= 656)	Score 2 (n= 193)	Score 3 (n= 254)	Score 4 (n= 201)	Score 5 (n= 429)	
Gender							
Female	760 (43.9)	277 (16.0)	97 (5.6)	121 (7.0)	90 (5.2)	175 (10.1)	
Male	973 (56.1)	379 (21.9)	96 (5.5)	133 (7.7)	111 (6.4)	254 (14.7)	
Grade							***
1	337 (19.4)	145 (8.4)	24 (1.4)	39 (2.3)	21 (1.2)	108 (6.2)	
2	321 (18.5)	100 (5.8)	31 (1.8)	39 (2.3)	33 (1.9)	118 (6.8)	
3	363 (20.9)	131 (7.6)	36 (2.1)	70 (4.0)	42 (2.4)	84 (4.8)	
4	353 (20.4)	152 (8.8)	42 (2.4)	44 (2.5)	47 (2.7)	68 (3.9)	
5	359 (20.7)	128 (7.4)	60 (3.5)	62 (3.6)	58 (3.3)	51 (2.9)	
Refusal							***
Yes	1352 (78.0)	656 (37.9)	193 (11.1)	249 (14.4)	176 (10.2)	78 (4.5)	
No	381 (22.0)	0 (0.0)	0 (0.0)	5 (0.3)	25 (1.4)	351 (20.3)	

Note: data are presented as pure numbers (% of the total sample). A Pearson chi-square test was used to test the association of all categorical variables with liking groups; *** significant difference at $p < 0.001$.

Those results suggest that the youngest classes, in both the case studies, and males, only in the LOC-ORG case, appreciated more vegetables compared to their counterparts. Moreover, among the children who consumed all the vegetables offered to them, no one indicated that he/she did not appreciate the vegetables.

3.3.3.3 Nutritional impact of plate waste

Significant differences in the actual intake in terms of energy ($p < 0.01$), proteins ($p < 0.001$), carbohydrates ($p = 0.018$) and dietary fibre ($p < 0.001$) were found comparing the two case studies (Table 8). The higher consumptions in children attending the LOC-ORG schools can be explained by a significantly less nutritious plate waste (in terms of carbohydrates), a significantly higher nutritional content in the meals offered to children (in terms of dietary fibre), or both (in term of proteins). By adjusting for energy and nutrient amounts of plate waste, children in the LOC-ORG schools consumed 74% of the total energy of the offered lunch, accounting for a 10% more than children in the ORG schools (Figure 3). In terms of macronutrients, the percentages of loss ranged from 16% to 31% in the LOC-ORG schools and from 31% to 45% in the ORG schools. In both cases the minimum extreme referred to cholesterol, while the maximum referred to soluble sugars. Within these intervals, in the LOC-ORG case, proteins and saturated fatty acids showed the highest intake (77%), followed by total fat (74%) and carbohydrates (73%). On the other hand, in accordance

with the high plate waste of vegetables, dietary fibre was the food component with the lowest intake (70%). Similarly, in the ORG model, higher intakes were reported for proteins (66%), carbohydrates (64%) and fat (63%), while dietary fibre was highly wasted resulting in a lower intake (57%).

Considering micronutrient actual intake, significant differences between the two case studies were observed for approximately half of the considered vitamins and minerals, as displayed in Table 9. By comparing the two case studies, different intakes for vitamin B_1 (thiamin) and B_2 (riboflavin) were computed ($p < 0.05$), with children in the LOC-ORG showing the highest consumption, consistently with the relative plate waste data showing grater losses in the ORG case. The greater vitamin C, potassium (K), phosphorous (P) and iron (Fe) intakes in LOC-ORG case reflected whereas the relative disproportion found in the served lunches. In addition, Significant differences between the case models were reported for vitamin A, vitamin B_9 (folate) and calcium (Ca) intakes. However, for these micronutrients, the data were comparable when the offered lunches and the plate waste were considered. This finding can be explained by the varying data distribution that, even if it did not show significant differences in relation the served lunches and plate waste, allowed detecting different nutritional patterns in the actual intake.

In terms of percentages, the micronutrient losses for vitamins ranged from 15% (vitamin D) to 30% (vitamin A) and from 22% (vitamin D) to 45% (vitamin B_9) in the LOC-ORG and ORG model, respectively (Figure 3). In both case studies, vitamin D and vitamin B_{12} registered the highest intake (85% and 84% in LOC-ORG case; 78% and 70% in the ORG case); the absolute values did not differ between the two case studies, even in relation of the percentage of loss. These data converge with the preferential consumption of protein-based foods by children compared to other food categories and suggest that products of animal origin were less wasted. On the contrary, because of the consistent waste of fruit and vegetables, vitamin C, folate and vitamin A achieved the lowest intakes (respectively 72%, 71% and 70% in the LOC-ORG; and 55%, 55% and 57% in the ORG) that significantly differed between the case studies. Among the minerals, the loss percentages ranged from 16% (cupper) to 29% (sodium) in LOC-ORG schools and from 33% (cupper) to 41% (calcium) for ORG (Figure 3).

Table 8. Macronutrient composition and fibre content of served lunches, plate waste and actual intake in the LOC-ORG (n=20) and ORG model (n=19).

	Served lunches		Plate waste		Actual intake	
	LOC-ORG	ORG	LOC-ORG	ORG	LOC-ORG	ORG
Energy (kcal)	705.5 ± 91.4	690.6 ± 73.6	184.3 ± 39.2	248.6 ± 55.4***	521.2 ± 69.8	442.0 ± 79.5**
Proteins (g)	30.5 ± 5.9	26.9 ± 4.7*	6.9 ± 1.9	9.1 ± 3.1*	23.6 ± 4.8	17.8 ± 4.1***
Carbohydrates (g)	104.1 ± 12.1	103.6 ± 13.3	28.5 ± 6.0	37.3 ± 8.5**	75.6 ± 10.3	66.2 ± 13.5*
Soluble sugars (g)	22.6 ± 6.5	22.4 ± 8.4	6.8 ± 3.6	9.5 ± 4.4*	15.7 ± 5.6	12.8 ± 7.5
Dietary fibre (g)	12.9 ± 3.5	9.4 ± 3.3**	3.9 ± 1.4	4.1 ± 1.7	9.0 ± 2.7	5.3 ± 2.0***
Fat (g)	20.4 ± 7.1	20.8 ± 4.6	5.2 ± 1.9	7.7 ± 2.8**	15.2 ± 5.8	13.1 ± 3.5
SFA (g)	7.0 ± 6.4	5.8 ± 3.2	1.4 ± 1.0	2.1 ± 1.5	5.6 ± 5.5	3.7 ± 2.0
Cholesterol (mg)	49.8 ± 34.4	68.2 ± 57.8	8.8 ± 7.3	23.8 ± 29.1	41.0 ± 27.8	44.5 ± 34.6

Note: data are expressed as mean ± SD. *p* values refer to between-group comparison (LOC-ORG *vs.* ORG), parametric *t* test. SFA: saturated fatty acids; ns: not significant ($p > 0.05$). *, **, *** significant differences at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively. The nutritive values of served ORG lunches slightly differ from the data displayed in Table 3 as based on 19 instead of 20 lunch school menus.

Table 9. Micronutrient composition of served lunches, plate waste and actual intake in the LOC-ORG (n=20) and ORG model (n=19).

	Nutritional composition of served lunches		Nutritional composition of plate waste		Actual intake	
	LOC-ORG	ORG	LOC-ORG	ORG	LOC-ORG	ORG
Vitamins						
A (mg RE)	653.3 (436.8-1385.6)	470.4 (312.3-751.1)	236.3 (93.5-418.8)	226.5 (110.6-6.9)	406.7 (316.0-939.2)	244.7 (167.3-375.6)**
B_1 (mg)	0.5 (0.4-0.6)	0.4 (0.4-0.5)	0.1 (0.1-0.2)	0.2 (0.1-0.2)**	0.3 (0.3-0.4)	0.3 (0.2-0.3)*
B_2 (mg)	0.4 (0.3-0.5)	0.4 (0.3-0.4)	0.1 (0.1-0.1)	0.1 (0.1-0.1)*	0.3 (0.2-0.4)	0.2 (0.2-0.3)*
B_3 (mg)	4.5 (3.7-6.8)	5.1 (3.9-6.7)	1.0 (1.0-1.2	1.7 (1.4-2.2)**	3.5 (2.8-4.8)	3.2 (2.2-4.5)
B_6 (mg)	0.7 (0.6-0.8)	0.8 (0.6-0.9)	0.2 (0.1-0.2)	0.3 (0.2-0.3)**	0.5 (0.4-0.6)	0.5 (0.5-0.6)
B_9 (µg)	108.7 (92.1-142.7)	100.7 (69.7-121.4)	33.3 (25.1-43.0)	42.0 (23.7-52.5)	77.1 (63.4-99.7)	50.6 (38.2-63.6)**
B_{12} (µg)	1.3 (0.4-1.6)	1.2 (0.9-1.8)	0.2 (0.1-0.3)	0.3 (0.2-0.5)	1.1 (0.3-1.3)	0.8 (0.6-1.1)
C (mg)	82.0 (56.9-106.3)	48.9 (21.7-72.8)**	21.9 (15.0-38.0)	15.3 (10.0-33.8)	53.7 (35.6-63.6)	19.8 (13.1-33.2)***
D (µg)	0.2 (0.1-0.4)	0.2 (0.1-0.6)	0.0 (0.0-0.1)	0.1 (0.0-0.1)	0.2 (0.1-0.3)	0.2 (0.1-0.4)
Minerals						
Na (mg)	585.6 (506.8-768.9)	521.9 (447.3-864.9)	169.3 (155.7-192.9)	231.2 (165.2-274.9)	431.5 (347.0-528.8)	307.8 (238.6-532.2)
K (mg)	1275.7 (1051.9-1378.8)	1050.1 (807.9-1292.4)*	343.9 (275.2-411.0)	425.9 (346.8-456.4)	908.7 (770.0-1045.6)	652.3 (490.3-775.9)**
Ca (mg)	279.7 (261.2-321.5)	258.0 (193.9-314.1)	84.2 (73.7-103.4)	100.2 (72.2-146.5)	205.2 (177.8-231.0)	158.1 (104.3-206.7)*
P (mg)	482.0 (440.2-543.7)	424.2 (377.6-479.1)**	115.3 (102.3-140.4)	149.8 (111.9-174.6)	380.3 (349.7-422.0)	285.6 (221.5-297.5)***
Mg (mg)	42.9 (26.0-63.6)	31.9 (29.0-55.1)	9.8 (7.6-14.2)	12.9 (10.0-17.4)	33.3 (19.6-46.2)	23.7 (16.5-37.1)
Fe (mg)	4.8 (4.3-5.9)	3.9 (3.6-4.6)**	1.5 (1.2-1.6)	1.5 (1.1-2.0)	3.6 (2.8-4.2)	2.4 (2.0-2.9)***
Zn (mg)	3.4 (2.6-3.9)	3.1 (2.7-3.9)	0.7 (0.6-0.8)	1.1 (0.8-1.3)***	2.6 (2.1-3.1)	2.0 (1.8-2.7)
Cu (mg)	0.3 (0.1-0.5)	0.2 (0.1-0.5)	0.1 (0.0-0.1)	0.1 (0.0-0.1)	0.2 (0.1-0.4)	0.1 (0.1-0.3)

Note: data are expressed as median (IR) given the non-normal distributions. Vitamin A is expressed as retinol equivalent (RE). *p* values refer to between-group comparison (LOC-ORG vs. ORG), non-parametric Mann-Whitney test *, **, *** significant differences at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

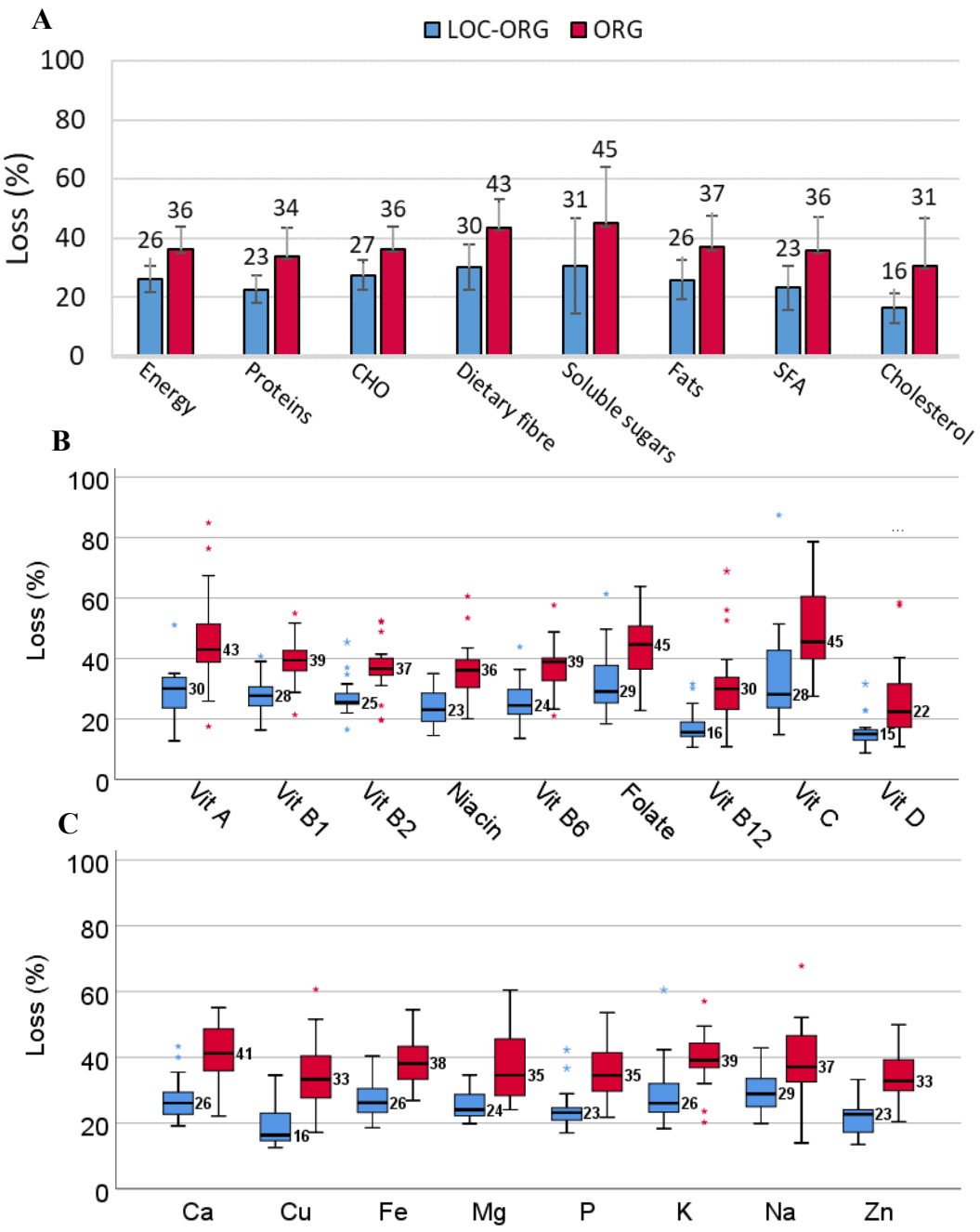

Figure 3. Losses of energy and macronutrients (A); vitamins (B); minerals (C) of school lunches in the LOC-ORG (n=20) and ORG model (n=19). Data are expressed as mean ± SD for A, and median (IR) for B and C given their non-normal distributions.

By adjusting for plate waste values, menu distributions according to the national recommendations underwent to considerable changes, except for the proportion of the energy provided by total proteins, fats and carbohydrates that did not substantially differ (Figure 4). Energy and nutrient contents of plate waste negatively impacted the compliance of school lunches with the national standards. In terms of energy, half of the LOC-ORG lunches reached the minimum cut-off, while the remaining 10 menus were below it. The LOC menus had a higher detrimental impact, with only 21% of the menus being in the optimal energy range. In terms of carbohydrates, no LOC-ORG lunches were above the recommendation, while the 40% of them were lower the standards. Similarly, no LOC-ORG lunches overcame the maximum soluble sugar content, while 30% of them appear below the minimum. An even worse distribution can be observed for the ORG menus, as only less than half of them was in compliance with the recommendations for both carbohydrates (26%) and sugars (42%). The impact on the fibre content was not particularly detrimental for the LOC-ORG menus as it caused the occurrence of a low proportion (15%) of school lunches below the national standards. On the contrary, most of ORG menus (58%) fell within this category.

The best nutritional outcomes after considering plate waste were found for the protein content, since all the LOC-ORG menus and 84% of the ORG menus met the standards. The fat content received the highest negative impact from plate waste, with most of the lunches showing a value below the recommendations in both case studies (85% and 89% respectively in the LOC-ORG and ORG model). The saturated fatty acid content was not affected by plate waste in the LOC-ORG schools, whereas none of the menus in ORG schools was above the upper reference limit. In terms of micronutrients, the share of menus under the recommended value in the ORG schools was 100% for iron content and the 95% for calcium. The number of menus in the same category increased also for the LOC-ORG model, with 90% of menus having an adequate iron content, while no change occurred in relation to calcium.

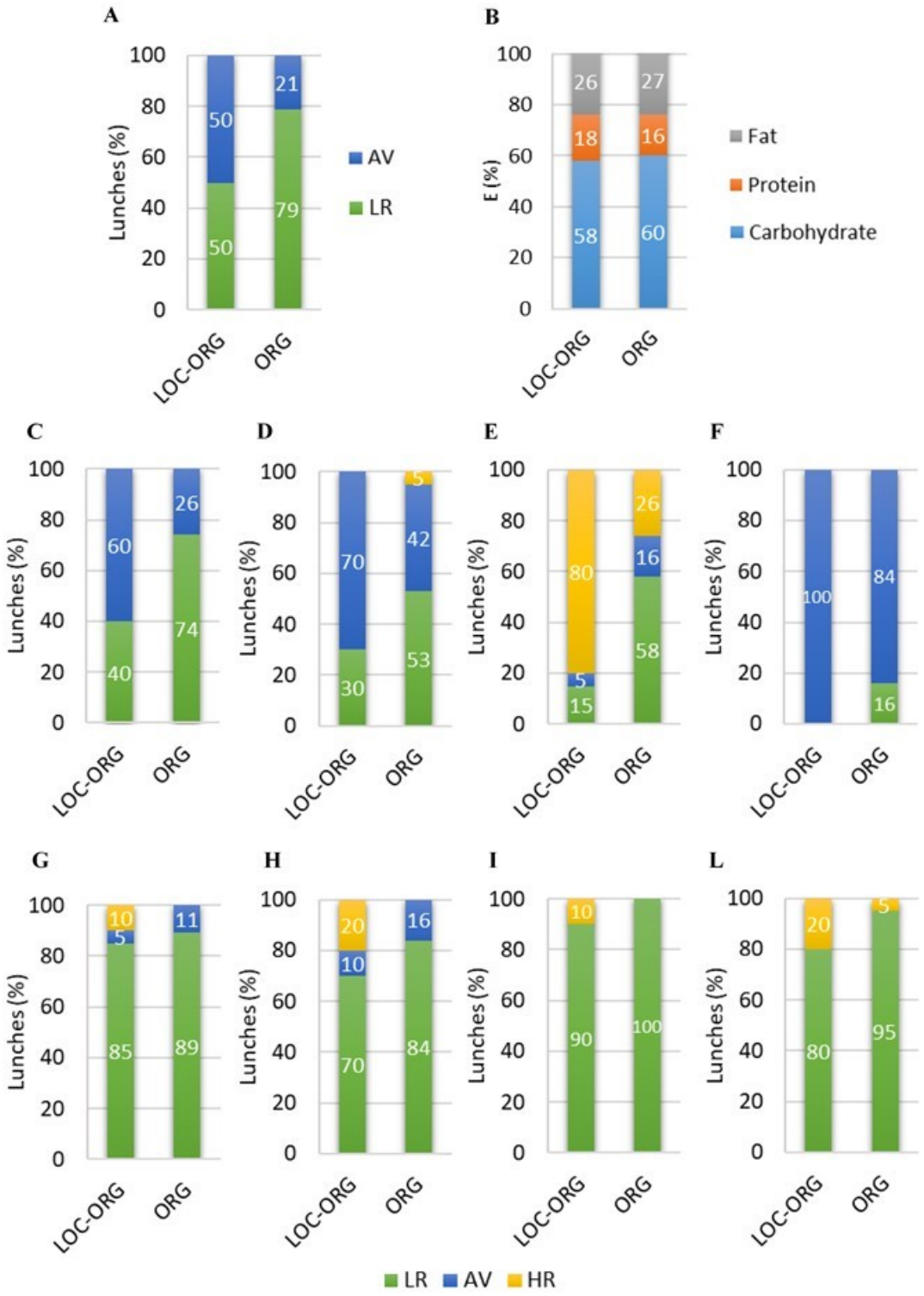

Figure 4. Distribution of school lunches after adjusting for plate waste in the LOC-ORG (n=20) and ORG model (n=19) according to National recommendation referred to energy (A), carbohydrates (C), soluble sugars (D), dietary fibre (E), proteins (F), fats (G), saturated fatty acids (H), iron (I), and calcium (L). Average percentage of energy provided by total protein, fat and carbohydrate content (B) of school lunches in the LOC-ORG (n=20) and ORG (n=19) model. AV: adequate value; HR: higher than recommendation; LP: lower than recommendation.

3.3.3.4 Carbon impact of plate waste

Table 10 shows the GHG emissions generated by food waste in the LOC-ORG schools. As described in Section 2.2.4, the estimations are based on the total meals served within the sample of five schools per case study. At production stage, the wasted "other" category, followed by the starchy foods registered the highest impact in terms of CO_2eq emissions and all together represented about 76% of the food production emissions and 72% of the global impact. Starchy-based dishes registered an average EF of 1.89 kgCO_2eq/kg, whereas for the "other" category the average impact was 2.28 kgCO_2eq/kg of food waste. It is possible that this figure was overestimated due to the limited time-span along which the food waste analysis in the schools has been carried out. Protein-based dishes contributed with a share of 12% to the total food waste CO_2 impact due to the production phase. On average, each kg of plate waste coming from the LOC-ORG school lunches corresponded to 1.68 kgCO_2eq. Food production accounted for 96% of the total waste CO_2 burden. This means that most of the food waste emissions was due to avoidable emissions at agricultural and processing phases. The transportation of food destined to be wasted was not very significant (2% of the total food waste emission), as well as the food waste management (3%). This latter small percentage was due to the composting system adopted in the municipality that contributed to mitigate the impact of food waste treatment. The total waste emissions burden in the LOC-ORG case was 90,247 kg, i.e. 36% of the total CO_2 emissions impact due to the food supplied by Parma Cater, estimated to be 252,395 kgCO_2eq. For each average school lunch served in LOC-ORG schools, the CO_2eq emission content due to food waste was 0.34 kgCO_2eq.

In the ORG model, starchy foods and protein-based dishes had the highest impact in terms of CO_2 emissions at production stage. These two categories represented about 69% of the waste impact due to the food production level. Starchy-based foods comprised an average EF of 1.78 kgCO_2eq per kg of food waste, whereas for protein-based dishes the average impact was 4.41 kgCO_2eq per kg of food waste. The dessert was the third most emissive food waste category accounting for 16% of the total food waste emissions. Fruit and vegetables represented together about 13% of the total impact, although the weight of food waste for these categories was more than 50% of the total weight of food waste. Indeed, the average EFs for fruit and vegetables were 0.35 and 0.34 kgCO_2eq/kg, respectively. The plates included within the "other"

category represented just 3% of the entire food waste CO_2 emissions produced by the five ORG schools. On average, each kg of plate waste produced by in the sampled ORG schools corresponded to 1.34 $kgCO_2eq$ emissions. The total CO_2 emissions related to production was 92% of the total waste CO_2 burden, a percentage similar to the LOC-ORG schools. The transportation of food destined to be wasted was not very significant (5% of the total food waste emissions), as well as the food waste management (3%), which was based on composting system as in the LOC-ORG case. The total CO_2eq waste burden in the ORG case was 46,256 kg, i.e. 35% of the total CO_2 emissions impact due to the food supplied by of the Lucca Cater, estimated to be 132,160 $kgCO_2eq$. For each average lunch meal served in Lucca schools, the CO_2eq emission content due to food waste was 0.37 $kgCO_2eq$.

No significant statistical differences in the food waste carbon emission intensity ($kgCO_2eq/kg$) characterised the food waste categories by comparing the two case studies (Table 10). However, different patterns of food waste composition explain why the CO_2 burden per kg of plate waste in the ORG schools was 17% lower than in the LOC-ORG schools. In Parma (LOC-ORG model), the average carbon EFs for fruit and vegetables were respectively 0.28 and 0.23 higher than in Lucca (ORG model) and a greater difference (1.36) can be observed for the "other" category. In addition, for the protein-based dish category, the LOC-ORG schools showed less emissions (12.2% of the total production emission), while the ORG schools the percentage was higher (31% of the total production emissions). These results reflect the inclusion of products emitting higher CO_2 levels in the ORG model compared to the LOC-ORG model, as shown by the average EF. In particular, the food items that contributes within the protein-based plates to the highest CO_2 emissions in Lucca are meat and fish (50%), and soft and hard cheese (37%). Furthermore, the share of protein-based dishes in the ORG model is higher than in the LOC-ORG one (9.5% *vs*. 5.9%).

Table 10. Estimated embodied carbon in plate waste per year from LOC-ORG and ORG case study.

	Waste (kg)		Waste (%)		GHG emissions ($KgCO_2eq$)		Average EF ($kgCO_2eq/kg$)	
	LOC-ORG	ORG	LOC-ORG	ORG	LOC-ORG	ORG	LOC-ORG	ORG
Starchy food	15,797	8,901	30.7	28.1	29,929	15,858	1.89	1.78
Protein-based dish	3,017	3,022	5.9	9.5	10,666	13,235	3.54	4.41
Vegetables	6,583	5,943	12.8	18.8	4,059	2,040	0.62	0.34
Fruit	10,501	9,945	20.4	31.4	6,134	3,457	0.58	0.35
Dessert	-	2,518	-	8.0	-	6,580	-	2.61
Other	15,505	1,334	30.2	4.2	35,398	1,228	2.28	0.92
CO_2 burden (food production)	51,403	31,664	100.0	100.0	86,186	42,488	1.68	1.34
Transportation [a]					1,542	2,216	0.03	0.07
Waste handling					2,519	1,552	0.05	0.05
Total Waste CO_2 Burden					90,247	46,256	1.76	1.46

Note: [a] This step along the supply chain refers to the distance between the central kitchen and the schools. The estimate data refer to the school lunches offered in a sample of five schools in the LOC-ORG and ORG model during the school year. Between-group comparison of average EF, Mann Whitney non-parametric test. EF: emission factor; Not significant differences ($p < 0.05$) have been found by comparing the two case studies for the Average EF data.

3.3.3.5 Economic impact of plate waste

Table 11 displays an estimation of the economic impact of food waste along an entire school year for five schools per each case study. In the LOC-ORG case, the food category with the highest economic loss from the plate waste was starchy food (37% of the total cost). In this category, bread represented about one third of the food waste cost, followed by Parmigiano-Reggiano cheese (20%) that was include in the same category because it was used also as ingredient to prepare starchy-based recipes. Fruit and vegetables all together represented 22% of the total plate waste cost and accounted for 33% on total food waste. The "other" category accounted for the remaining 20% of the total cost. In the LOC-ORG model, 51,403 kg of food waste corresponded to a total cost of about € 84,800 per year, i.e. a cost per kg of food waste of € 1.65.

In the ORG case, the food category with the most relevant cost due to food waste was the starchy food (29% of the total cost). In this category, bread represented more than one third of the food waste cost, followed by canned tomato (30%). Similarly to Parmigiano in the LOC-ORG case, canned tomato was included in the starchy-food category as it represents an ingredient used to prepare such recipes. Fruit and vegetable-based plates represented 21% of the total cost. Wasted desserts showed a share of 19%, while the "other" category accounted for the remaining 10%. In the ORG model, 31,664 kg of food waste corresponded to a total cost of about € 88,400 per year, i.e. a cost per kg of food waste of € 2.79.

In both case studies, although protein-based plates showed a share of less than 10% on the total volume of food waste, they accounted for 21% of the total food waste cost. In this category, the most expensive food item was the cod fish for the LOC-ORG case (47% of the total cost) and fresh cheese (stracchino and robiola accounting for 35% of the total cost), followed by turkey meat (13%) and bresaola (11%), for the ORG model. The cost per kg of food waste was 69% higher in the ORG case than in the LOC-ORG one. This was due to the different plate waste for the two cases, which affected the unit cost of each item and therefore the total plate waste cost. More specifically, even if not statistically significant differences were found, most of the food categories showed a higher average cost per kg of plate waste than the in the LOC-ORG case. Vegetables represented the unique exception, with a statistically significant higher value (p=0.03) obtained for the LOC-ORG compared to the ORG model. The type of plates and the ingredients used for their preparation can explain

these findings. The higher costs registered per kg of food waste was confirmed also by the cost per meal: in the ORG model, the estimated cost of plate waste per meal was more than double compared to the LOC-ORG model (0.70 €/meal *vs.* 0.32 €/meal). In relative terms, the estimated cost of plate waste represents 5.2% and 14.0% of the full price paid by parents, respectively, in the LOC-ORG and ORG model.

The share of each food category on the total food waste costs was quite similar across the cases, with the exception of protein-based dish, "other" food and dessert that showed relatively higher values in absolute terms. In both the cases, the impact of the costs of plate waste on the contract budget was significant. However, for Lucca municipality its high level greatly affects the socio-economic sustainability of the entire school meals procurement. According to the estimates, for Lucca municipality (ORG model) the total economic loss associated with plate waste as a proportion of the total food procurement cost was 34%, while for Parma municipality (LOC-ORG model) the plate waste cost accounted for 18% of the school meal service budget.

Table 11. Estimated embodied carbon in plate waste per year from LOC-ORG and ORG case study.

	Waste (kg)		Waste (%)		Cost (€)		Average cost (€/kg)	
	LOC-ORG	ORG	LOC-ORG	ORG	LOC-ORG	ORG	LOC-ORG	ORG
Starchy food	15,797	8,901	30.7	28.1	31,098	25,748	1.97	2.89
Protein-based dish	3,017	3,022	5.9	9.5	18,777	18,585	6.00	6.15
Vegetables	6,583	5,943	12.8	18.8	8,928	6,736	1.36	1.13*
Fruit	10,501	9,945	20.4	31.4	10,046	11,985	0.96	1.21
Dessert	-	2,518	-	8.0	-	16,554	-	6.57
Other	15,505	1,334	30.2	4.2	16,632	8,773	1.07	6.57
Total	51,403	31,664	100.0	100.0	84,806	88,381	1.65	2.79

Note: p values refer to between group comparison (LOC-ORG vs. ORG), Mann-Whitney non-parametric test. * significant differences at $p < 0.05$

3.3.4 Discussion

In this study the impact of plate waste was assessed in a primary school context using a multi-target approach to evaluate nutritional, environmental and economic implications. The performed evaluation provides an insight of the nutritional, environmental and economic costs of plate waste, which directly affect children and their families and contributes to an in vain exploitation of natural resources.

The two case models reported different results, with the LOC-ORG model showing lower waste percentages than the ORG one. Across food categories, in both case studies, vegetables were the most wasted, followed by fruit and bread. The percentage of wasted plant-based food (i.e. fruit and vegetables) was notably higher in the ORG case, where pupils consumed less than 50% of the median offered portion size. However, the issue of vegetables discard was evident in all schools and appears to be associated with children's liking and picking behaviours. The quantification of fruit and vegetable plate waste has been described in several articles reporting similar or higher percentages (Liu *et al*., 2016), with equal or distinct patterns among them (Dinis, Martins, and Rocha 2013). Conversely, in case of multiple choice menus (*vs.* one set menu), vegetable items (e.g. salad) could be the most offered, showing however a low level of acceptance (Marlette *et al*., 2005), as the least popular food (Ishdorj *et al*., 2015), and a low waste percentage compared to more energy dense products (e.g. boiled potatoes). Since fruit and vegetable intake has been associated with prevention of chronic diseases, by reducing the risk of total mortality and in particular the risk of cardiovascular mortality (Aune *et al*., 2017; Wang *et al*., 2014), the high plant-based product waste is a major concern for public health. Conversely, the protein-based dishes in the LOC-ORG case model and (semi)unique dishes in the ORG case registered the lowest waste percentages. From the analysis of the nutritional consequences of plate waste, a higher detrimental impact was reported for the ORG model compared to the LOC-ORG one, due to the higher energy and nutrient losses. On average, compared to the meal offered at school, the loss of energy and macronutrients was approximately 10% greater in the ORG than in the LOC-ORG model. In both models, the intake of proteins was slightly higher compared to carbohydrates and fats. On the other hand, the lowest intake was obtained for soluble sugars and dietary fibre, in accordance with plate waste data. Beyond these considerations, when adjusted for plate waste data half or more than half of the lunch

menus fell below the national energy recommendations in both case studies. Moreover, from 15% to 100% of the school lunches showed nutrient contents below the national standards when plate waste is considered. These findings strongly encourage investigating the contextual factors that could affect plate waste targeting its minimisation.

Comparing the results of the present study with the literature, similar energy and nutrient values with regards to the planned school lunches were observed. Cohen and colleagues (2013), who addressed their research to middle school students in US, reported an average energy (660 ± 13 kcal) and fat content (18.6 ± 0.7 g) slightly below the results presented. The average fibre (9.5 ± 0.4 g) and saturated fatty acid content (6.2 ± 0.2 g) were instead comparable with the ORG data (Cohen *et al*., 2013). Nevertheless, when adjusting with data on plate waste, on average, the actual energy and nutrient intakes in the US registered lower values than the LOC-ORG or ORG cases, with the exception of total fat and saturated fatty acids that were similar to the ORG case study (Cohen *et al*., 2013). In terms of energy and nutritional adequacy with the recommendations, Dinis and colleagues (2013) found a lower proportion of lunches being compliant with national standards compared to the LOC-ORG or ORG models. Their study involved a Portuguese primary school having stricter national energy and nutritional standards compared to the Italian ranges of reference. In the Portuguese school plate waste analysis showed relatively higher percentages for vegetables (<60%), while fruit was less wasted (24%) compared to the results in the two Italian case studies. The percentage of plate waste referred to carbohydrates was instead similar to the ORG case (Dinis *et al*., 2013). Protein-based dishes were more wasted by Portuguese children, with fish showing in particular higher levels (55% *vs.* <35%) (Dinis *et al*., 2013).

Conversely to what suggested by the present results, two studies conducted in the US showed a declining trend in the vegetable plate waste from the first to the fifth grade school children (Smith and Cunningham-Sabo 2014; Niaki *et al*., 2017), while no significant gender difference was observed (Smith and Cunningham-Sabo, 2014). Within the Italian primary school context, Boschini and colleagues, who recruited five primary schools in Bologna province, reported the highest plate waste percentage for the side-dish (35%) (Boschini *et al*., 2018); this figure is comparable to the plate waste percentage found for vegetables in the LOC-ORG case. The authors reported instead

a significantly lower plate waste for bread (8%), either compared to the LOC-ORG or ORG case.

With regards to the environmental impact of plate waste, different patterns were found between the cases: the most carbon emissive food categories were starchy and "other" food categories in the LOC-ORG case and protein-based plates and starchy food in the counterpart. The different composition of the food waste reflects the food waste carbon footprint burden being 17% lower in the ORG compared to the LOC-ORG model. Overall, the carbon emissions due to food waste embedded in the meal of LOC-ORG and ORG cases accounts for 36% and 35% respectively. In a similar study on the analysis of the environmental impact of the school canteen food waste in the nursery and primary public schools of Cento (Italy), García-Herrero and colleagues (2019) estimate a Global Warming Potential of food waste ranging between 15-18% of the total meal impact. The quite high discrepancy is mainly due to the different food waste composition observed in the surveyed school canteens. In our study, the starchy carbohydrate plate (i.e. mainly first course and bread) was the most discarded plate by pupils in the two typologies of schools, followed by fruits while in the case of Cento's study, vegetables (i.e. side dish) seem to contribute most to the total food waste.

The environmental impact assessment suggests that food waste is not just detrimental for the pupils' nutritional intake but also for natural resources and collective wellbeing. As the results demonstrated, a significant quota of the carbon emissions embedded in school meal is ascribable to discarded food. In particular, the total CO_2 emissions related to production represented the major share of the total waste CO_2 burden. This means that the most part of the food waste emissions was due to avoidable emissions at agricultural and processing phases. In this respect, the literature suggests that the method of food production can greatly affect the climate change impact of food. In general, organic productions reveal a lower efficiency in using natural resources than the conventional production (Buratti *et al*., 2017; Chiriacò *et al*., 2017). This is a debated topic in scientific literature which emphasises the role of agricultural production systems in determining the environmental sustainability of the whole food supply chain (González *et al*., 2019; Gomiero, 2018; Suciu, Ferrari, and Trevisan, 2019). The key variable driving the environmental impact is the production yield. Organic systems are typically characterised by lower production yield than conventional systems resulting in less favourable environmental indicators. According

to this argument, a change in food procurement may be beneficial to climate change mitigation of school meals and discarded foods. However, the supposed environmental inefficiency of organic productions characterizes mainly the most widespread impact categories, such as carbon footprint or water footprint.

From an economic perspective, the two food procurement models differed not only in terms of the cost of food waste but also in terms of the economic loss per kg of food waste that was 69% higher in the ORG than in the LOC-ORG case. The different food composition of plate waste explains these patterns. For families, the cost of plate waste is a significant piece of the budget spent, ranging from 5% (LOC-ORG model) and 14% (ORG model) of the full price paid by parents per lunch meal. These findings for LOC-ORG case are consistent with other studies, which estimate a costing impact of the food waste in school canteens ranging from 6% to 26% of the total meal cost (García-Herrero *et al*., 2019; Cohen *et al*., 2013). The economic value of plate waste represents a significant share of the total school meals service budget too. In the LOC-ORG, about 18% of the entire budget for food procurement is spent for food that will be discarded by children, whereas in the ORG case the share reaches 34% of the total food procurement budget. These values lead to a different plate waste cost per meal which is 50% less in LOC-ORG schools compared to ORG schools.

As suggested by the results, starchy food is one of the most important wasted food category during the lunch. In this respect, under the assumption that it could be possible to halve the quantity of wasted bread, as a result of a more careful and aware children behaviour, LOC-ORG case would reduce by 4% the carbon emissions and slightly more than 5% the costs due to food waste, while the carbon emissions and economic costs of ORG case would reduce by 2.3% and 2.5%, respectively. Conversely, a hypothetical reduction by 50% of the plate waste referred to the entire starchy food category (including bread) would lead to 36% reduction of the carbon emission for LOC-ORG with a cost reduction above 28%; for the ORG case, this hypothesis would mean a reduction in carbon emissions of 19% and a reduction in food waste costs of 20%. A sensitivity analysis conducted by García-Herrero and colleagues (2019) on school canteen environmental effects reveals that the variability in LCA-based emission factors for the different food items and the food market price fluctuation can affect the food waste impact analysis in terms of result uncertainty. In our study, a wide range of LCA emission factors was adopted for mitigating the level

of uncertainty in the environmental results; while for market food prices we adopted a short-run perspective using average yearly prices.

3.3.4.1 Possible plate waste determinants

According to the regional law and contract indications, it is plausible that the higher share of local/traditional quality products (i.e. PDO and PGI products), more familiar for children in the LOC-ORG model, could have played a role in partially explaining the differences in plate waste. The inclusion of a higher quantity of products originating from the local territory seems to contribute to a greater intake of the school menus in children and consequently to a lower food waste. However, contract specifications of school food procurement cannot exhaustively explain these findings. A multitude of factors linked to the contextual conditions affect pupils' actual food intake. Among these, meal recipes (Giboreau *et al*., 2019), food texture (Giboreau *et al*., 2019; Egolf, Siegrist, and Hartmann, 2018), type of preparation (e.g. raw or cooked food) (Bontrager Yoder, Foecke, and Schoeller, 2015), familiarity with certain food categories and food preference (Osborne and Forestell 2012; Edwards and Hartwell, 2002); canteen environment (Cordingley *et al*., 2011), teacher engagement (Martins *et al*., 2016) can be mentioned. Thus, beyond the different categorisation of the procurement models, relevant subject-dependent and independent variables should be considered to understand plate waste motives. Above all, the educational context was different in the two case studies. In the LOC-ORG case model a consolidate program of food and environmental education has been carried out by qualified personnel involving all primary schools since 2009. Conversely, a detailed food education course is not provided as part of primary school programs in the ORG case. Therefore, the growing awareness amongst children on nutritional and environmental issues in the LOC-ORG case might sway their food habits and behaviour towards plate waste and might explain the differences in the two case studies.

Moreover, teachers play a key-role during the school lunch not only addressing children to avoid leftovers, but also by encouraging fruit and vegetable intake (Martins *et al*., 2016). Supporting this position, beyond the different fruit consuming time - as a snack during the mid-morning break or after lunch - the large waste variability found between the classes of the same school is strictly dependent on the teachers' involvement and care in preparing and peeling the fruit for the different classes. Finally, in the school with the lowest percentages of fruit waste, the school headmaster

has forbidden pupils to bring in their own snack to school, as a deliberate strategy to discourage other food (primarily junk food) in favour of fruit. Furthermore, it should be noted that different waste management practices were adopted in the school canteens in the two case models, as established by the two catering companies. Only in the LOC-ORG case the percentage of waste in school canteens was measured and assessed on a monthly basis by the catering company to optimize the meal planning, preparation and distribution. Moreover, once children had concluded the lunch at school canteen, they had the responsibility to differentiate their leftover into separated bins. A different framework was instead found in the ORG model where, only in one of the two selected schools, older students used to assist in cleaning up the canteen, by clearing the tables at the end of the service.

Taken altogether, these findings suggest the importance of school governance (e.g. headmaster initiatives), school catering management (catering company organization), and school teachers' attitudes in driving children towards more sustainable food waste behaviours and habits.

3.3.4.2 Strategies to minimise plate waste

A potential strategy to increase vegetables consumption may be to serve the side-dish at the beginning of the lunch, taking advantage of the moment when pupils feel hungrier, a strategy already suggested in the literature (Elsbernd *et al*., 2016). Furthermore, offering dessert instead of fruit might increase fruit waste. Indeed, limiting dessert to special occasions may be a worthwhile strategy to encourage daily fruit consumption, educating children to consider the dessert as a food for a special occasion and not as part of their daily lunch routine.

The unique dish may represent an efficient strategy to reduce the food leftover offering the starchy-and protein-based dishes with vegetables in a single plate. This suggestion comes from the observation of the canteen environment that being quite chaotic and noisy can negatively impact children's eating behaviour. Hence, it is posited that it may be easier for pupils being concentrate on eating and limiting food waste when receiving a single dish in a unique occasion instead of receiving the menu across multiple plates and spread over time.

In parallel to these suggestions, a possible strategy for improving energy and nutrient intakes from school lunches could be a re-thinking of the National Guidelines

concerning standards portions. Indeed, the Italian recommendations for energy and nutrient contents of school lunches indicated in the national guidelines are addressed to primary school students, irrespectively of their grade, while different standard portions should be indicated due to different requirements depending on age, e.g. from 6 to 8 and from 8 to 11y.

3.3.5 Strengths and limitations

This study presents a multi-dimensional approach to assess the impact of plate waste generated by primary school children. To quantify plate waste a direct weighing method, which is considered the gold standard methodology for this assessment, was applied. Important limitations should however be recognised. First, the data collection involved a limited number of schools and was carried out during only two school weeks per school in the two case studies. As a consequence, the generalisation of our findings to other organic and local-organic procurement models in the Italian territory is questionable. Secondly, no validated national nutritional databases are available specifically for organic products. Therefore, the nutritional evaluation of school menus did not take into account possible discrepancies in the nutritional profile of organic products compared to the conventionally grown food, as reported in the literature (Palupi *et al*., 2012), even if alternative outcomes, with no or no robust evidence of significant differences were found (Galgano *et al*., 2016; Smith-Spangler *et al*., 2012). In this respect, organic products have been proved to have higher concentrations of bio-active compounds (e.g. (poly)phenolic compounds) and lower potentially harmful pesticide residues (Barański *et al*., 2014).

Moreover, it is worth noting that the plate waste percentage computed for each recipe was extended equally to all the ingredients used to estimate the energy and nutrient contents of plate waste and consequently the actual energy and nutrient intakes. To this regard, it has been assumed that the quantities of food that should have been served to children as planned by the catering service corresponded to those actually offered to the pupils. Indeed, the energy and nutritional calculations were based on the food quantities planned to be offered and not directly on the actual served food portions. Because of the limited number of available data, a statistical analysis to compare plate waste amount and the relative impacts between food categories and within each case study was not carried out.

A further limitation of the present study consists in not accounting for the proportion of processed but not served food by the catering service, providing thus a partial assessment of food waste generated in the school canteens. Such measurement would be used in parallel to plate waste analysis to provide an index of inefficiency of the school catering service (Falasconi *et al*., 2015).

Considering the environmental impact, further categories should be considered, e.g. human toxicity, eco-toxicity, biodiversity, animal welfare (Knudsen *et al*., 2019). Future comparison of the results achieved in this study with a new food procurement setting based on conventional food products should, thus, include and assess a wider set of environmental indicators.

Last, the present study estimates the economic impact of food waste in primary school canteens using the food prices comprised in national agri-food market survey datasets. Therefore, food waste cost was based on average food prices measured for national reference agri-food markets. As a consequence of the confidentiality content of the food procurement contracts between caterers and food suppliers, this analysis did not benefit from the actual information about the negotiated food prices. Therefore, the food waste costs should be considered as an estimate, whose reliability is affected by the agri-food market price variability, not evaluated in this study.

3.3.6 Conclusion

This study highlights the plate waste costs from the nutritional, environmental and economic perspective, by investigating two PSFP models in primary school settings. Beyond health risk, inadequate nutritional intake during the lunch implies greater food expenditure for families to compensate what their children do not eat at school. As a result, both the municipalities and the catering firms need to explore and develop new and effective strategies accounting for the school governance and catering management, as well as teacher's role to minimise the food discarded by children in school canteens. Plate waste minimisation requires strong efforts not just for improving the children's nutritional intake, but to allow a better environmental sustainability of the school meals service. Further investigations should be addressed to understand the contextual reasons of children's plate waste and develop interventions to improve the technical specifications of the school meals service procurement contract committing the school meals service supply chain to new

methods/techniques of menu design, meal preparation and distribution. Furthermore, at the national level, the national guidelines for school canteen should be revised, not only to reduce food waste but also to differentiate children nutritional needs according to their age and sex. In addition, nutritional and environmental education should be integrated into primary school programs in order to increase the awareness about nutritional and environmental issues associated to food waste in both children and teachers. A re-planning of the school meals service organisation and priorities is essential to decrease the inefficiency of the current system and to reduce food waste and its consequent nutritional, environmental and economic losses.

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Chapter 4
Overall Conclusions

The aim of this Doctoral Thesis was to investigate the eating behaviours of different target populations to then provide recommendations for the development of effective intervention strategies addressed to improve the sustainability of dietary behaviours in childhood and adulthood. The first part of the thesis was addressed at understanding and investigating the role of intrinsic and extrinsic factors in explaining and predicting the adoption of a sustainable diet, within a social-cognitive theoretical framework. The second part was focused on assessing eating behaviours of primary school children, by quantifying the nutritional, environmental and economic implications of school lunch plate waste.

As a first step, a systematic review was carried out to identify the main drivers and barriers towards sustainable diets in adults, by applying three psycho-social theories, i.e. the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour (TPB), and the Social Cognitive Theory (SCT). Most of the review studies (n = 60) were conducted in industrialised countries and only one among the health/nutritional, environmental and socio-economic dimensions was evaluated in each study. The former was the most considered, as the adoption and the intention to adopt a healthy or a low-fat diet were the most analysed variables. A multitude of significant predictors of intention and behaviour was found. The most recurrent were attitude for intention and intention for behaviour. When applied to dietary behaviour contexts, social-psychological models, in particular the TPB, can be chosen for their validity in predicting dietary behaviours and in explaining behavioural change. Indeed, the investigation and the understanding of consumers' behaviours are crucial for developing strategies and interventions to foster the transition towards more sustainable diets at the individual and population level. However, the analysis of the reviewed studies has shown that psycho-social models are more limited in explaining and predicting actual behaviour when prospective and more objective measures of food consumption are applied (e.g. food diaries and/or food frequency questionnaires).

Subsequently, based on the key findings of this systematic review and a preliminary qualitative phase, an online survey addressed to adults living in Italy was developed. A TPB questionnaire was set up and submitted to a representative sample of the Italian adult population to identify the most relevant predictive variables in explaining the intention to adopt a sustainable diet and the behaviour itself. Given the potential gap between actual and perceived behavioural performance, the adoption of

a sustainable diet was measured considering a) the individual's perceived behaviour, b) the adherence to the Mediterranean dietary pattern, and c) the frequency of consumption of single food groups. Significant associations were found between the TPB core constructs and the behaviour measures underlining the main role of intention and perceived behavioural control in influencing the behaviour. The application of structural equation models revealed a high capacity of the TPB to explain the intention to adopt the behaviour, while a lower predictive power was obtained when behavioural measures were operationalised as dependent variables. In line with the literature, the explained variance of behaviour was lower when an objective measure of behaviour was applied (i.e. the adherence to the Mediterranean Diet). The respondents showed a medium level of adherence to the Mediterranean Diet, confirming the shift from the Mediterranean dietary pattern in Italy, already emerged from the literature. Respondents only partially agreed to adopt a sustainable diet and approximately one-sixth of them associated the limitation of meat consumption to the concept of sustainable diet.

By identifying the drivers of consumers' behaviour and the associated beliefs, the findings of the TPB study may support policy makers in recommending and defining primary prevention interventions for enhancing consumer awareness and engagement towards more sustainable dietary habits. In particular, based on the obtained results, interventions targeting the adult population in Italy should be addressed to improve attitude and perceived control over behaviour. To pursue this objective, the following measures are highlighted:

- *Providing more information on the product labels*. Specifications about the geographical origin and, when possible, the environmental impact (e.g. carbon footprint, water footprint, land use, energy use) of the products available on the market should be listed as options. Information about the processing and the means of transportation used along the supply chain should be at least included, if more specific quantitative information is lacking. In addition, strengthening the information about the support potentially provided to the local economy and to small and medium producers obtained by purchasing sustainable products has the potential to be a driver of behaviour change.
- *Increasing food variety in collective catering.* A larger assortment of plant-based options should be offered by the catering services, while alternative options of

meat-based recipes should be limited. Appealing and tasty menus prepared with sustainable products should be proposed to increase consumers' acceptability. Moreover, providing indications on how to build sustainable and nutritionally balanced menus, by combining the available products on a daily basis, could be an effective strategy to trigger consumers' behavioural change.

- *Reducing the price of sustainable food products.* This recommendation is in accordance with previous evidence in the literature focusing on the effects of price change on dietary behaviour. Indeed, the application of subsidies aimed at reducing the final price of healthful products was found to be an effective strategy in increasing their intake.

The final part of the Doctoral Thesis was aimed at analysing and comparing two Italian cases studies (local-organic and organic public sector food procurement models) in relation to the impact of primary school children's plate waste by assessing the embedded nutritional, environmental and economic losses. In both cases vegetables were the most wasted food group – probably due to children's liking and picking behaviour – followed by fruits and bread. Conversely, protein-based dishes, (semi)unique dishes containing both starchy-based and protein-based products, and desserts were the least wasted. Overall, after adjusting for plate waste data, most of the lunch menus fell below the national energy and nutrient recommendations. (Semi)unique dishes, starchy food and protein-based dishes were found as the most relevant contributors to carbon emission. Moreover, a significant quota of the total waste CO_2 burden was ascribable to the agricultural and processing phases, these being the most emissive steps along the school meal supply chain. The different food composition of plate waste of the two case studies affected not only the relative carbon emission burden, but also the associated economic cost and the cost per meal. A relevant share of the entire budget for food procurement was spent for food that was discarded by children. Beyond the characteristics of the procurement models, relevant subject-dependent and independent variables should be considered to understand plate waste determinants. Based on the results of this study, some recommendations can be suggested to address the minimisation of plate waste in the Italian primary school context.

- *Supporting food educational programs.* A consolidate program of food and environmental education, carried out by a qualified personnel, could be considered

a valuable strategy to raise awareness amongst children and to sway their food habits and behaviour towards sustainable eating, including plate waste minimisation and prevention.

- *Defining school governance for healthy and sustainable eating behaviours.* Restrictive measures should be defined to prevent children from bringing snacks to school, with a specific focus on junk food. Fostering fruit consumption, discouraging energy dense products rich in fats and sugars, could be important not only for an educational dietary perspective, but also to optimise eating behaviour at lunch.
- *Addressing teachers' attitude during school lunch.* Teachers' role is paramount to encourage children to avoid plate waste and to eat more less familiar products. Moreover, during the mid-morning snack, when a fruit provided by the catering service is generally consumed by children, teachers' involvement and care in preparing and peeling the fruit could be considered an important measure to minimise food waste.
- *Addressing school catering management in serving lunch menus.* Serving the side-dish at the beginning of the lunch, as well as increasing the offer of unique dishes could represent effective strategies to minimise food waste. Experimental sessions with children should be performed to test the best solution to minimise waste.
- *Monitoring children's plate waste over time.* Constant quantification of plate waste allows to optimize future meal planning, preparation and distribution, and to evaluate the efficacy of the applied interventions. In addition, the engagement of the students in differentiating leftovers enables to form awareness among them about sustainability issues.
- *Redefining national guidelines for standard portions.* The Italian recommendations for energy and nutrient contents of school lunches, as reported in the national guidelines, are addressed to primary school students, irrespectively of their grade, while different standard portions should be highlighted, due to different requirements depending on age, e.g. from 6 to 8 and from 8 to 11y.

Chapter 5
Future perspectives

Based on the recommendations provided by the present Doctoral Thesis and a further preliminary qualitative analysis (i.e. in-depth interviews), an intervention study will be carried out starting from November 2019 in Parma. The study, recently approved from the local Institutional Ethical Committee (Comitato Etico Area Vasta Emila Nord, 862/2019/SPER/UNIPR), is aimed at investigating the best intervention strategy to improve young adults' diet sustainability in terms of nutritional and environmental impacts based on the TPB framework.

The primary outcome of the study will be the Mediterranean Diet adherence score, while the secondary outcomes will be represented by (i) nutritional impact of the students' dietary intake in terms of energy and macronutrient; (ii) the environmental impact (carbon, water and ecological footprint) associated to the subjects' food consumption; (iii) TPB-based questionnaire outputs, and iv) physical activity level.

The students of the University of Parma will be targeted and recruited according to specific criteria, such as being in the age range between 18 and 30 and eating alternatively at one of two University canteens (one located in the city centre and the other one at the University campus) at least 3 times/week. A number of 690 students will be enrolled at the University canteens assuming a potential dropout rate of 15%, with a final sample expected to include a minimum number of 600 students. The students who will agree to participate to the study will be screened according to inclusion criteria and, if eligible to participate, will be requested to sign the informed consent form to take part to the study. The enrolled students will be randomised in four groups that will be distinguished on the basis of the kind of interaction that will be established with the subjects and their degree of involvement within the study (1: no intervention; 2: soft, non-interactive intervention; 3: intermediate non-interactive intervention involving canteen environment modifications, 4: interactive forms of communication through e-mails and a dedicated mobile app).

The cafeteria can be considered a preferential setting to engage young adult consumers in sustainable dietary behaviours as it can provide easy access to sustainable menu options and it can opportunely drive the food choice if an enabling environment is created (Hendren & Logomarsino, 2017; Seymour, Lazarus Yaroch, Serdula, Blanck, & Khan, 2004). Moreover, an everyday-life perspective is applied, involving social and physical surrounding. To this regards, it is worth noting that a

change in dietary habits is strictly connected with a change in one's own values and practices, as eating sustainable is only one example of sustainable behaviours. Printed and digital communication tools aimed at informing, reminding, educating and empowering the participants will create a supportive environment towards diet sustainability. Finally, the interactive intervention will exploit gamification experiences as a mechanism to engage the students by triggering their motivations to adopt a sustainable diet (Sardi, Idri, & Fernández-Alemán, 2017). Therefore, the interactive intervention is expected to be the most effective in driving food choices and diet towards sustainability given the synergic combination of different behavioural change strategies.

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