A fibre syrup for the sugar reduction in fruit filling for bakery application

International Journal of Gastronomy and Food Science

A fibre syrup for the sugar reduction in fruit filling for bakery application

--Manuscript Draft--

Manuscript Number:	IJGFS-D-22-00043R3
Article Type:	Research Paper
Section/Category:	Science and gastronomy (chemistry, engineering, sensory science, microbiology)
Keywords:	Fruit filling; sugar reduction; fibre syrup; dietary fibre
Corresponding Author:	Eleonora Carini ITALY
First Author:	Alessandro Carcelli
Order of Authors:	Alessandro Carcelli
	Anna Albertini
	Elena Vittadini
	Eleonora Carini
Abstract:	Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new fibre syrup based on corn (Zea mais) dextrin and seed coats of chickpeas (testa of Cicer arietinum seed) has been used to formulate reduced-sugar fruit fillings. Three reduced-sugar (by 30, 50 and 70%) recipes were developed starting from a standard formulation, in order to reach the "reduced in sugar" and "high in fibre" label claims. Physicochemical and sensory properties of the fruit fillings were assessed during 180 days of storage at two different temperatures (5°C and 25°C). Increased hardness, adhesiveness, consistency coefficient (K, flow behaviour), bake stability and colour differences have been observed in reformulated recipes with increasing fibre syrup content if compared to the control. Storage decreased bake stability and induced darkening of the product in all samples. 30% sugar-reduced filling were the most appreciated by consumers, and not distinguishable from the control. Overall results confirmed the syrup technological functionality when used to obtain a 30% sugar-reduction.
Suggested Reviewers:	Hayette Louaileche haylouaileche@yahoo.fr
	Harald Rohm harald.rohm@du-dresden.de
	Santina Romani santina.romani2@unibo.it
Response to Reviewers:	

Manuscript Number: IJGFS-D-22-00043
A fibre syrup for the sugar reduction in fruit filling for bakery application

Response to the Reviewers second round

Reviewer #2: The Authors have made all suggested changes in the manuscript. There is one point that has to be addressed before publishing:

1. Fiber syrup color was not given numerically in CIE L*a*b* coordinates, only described, although it was stated in Material and Methods section that it was measured.

The values of L*, a* and b* coordinates have been reported in the "Results and Discussion" section.

A fibre syrup for the sugar reduction in fruit filling for bakery application

Alessandro Carcelli[13], Anna Albertini[1], Elena Vittadini[2], Eleonora Carini[1*]

[1] Department of Food and Drug, University of Parma, Parco Area delle Scienze 47/a, 43124 Parma, Italy

[2] School of Biosciences and Veterinary Medicine, University of Camerino, via Gentile III da Varano, 62032 Camerino, Macerata, Italy (current address)

[3]HI-FOOD S.p.A., Parco Area delle Scienze Pad. 27, 43124, Parma, Italy

[*] **Corresponding author**

E-mail address: eleonora.carini@unipr.it

address: Parco Area delle Scienze, 47/a, 43122 Parma, Italy

phone: +039 0521 906520

e-mail address of each author:

alessandro.carcelli1@studenti.unipr.it

anna.albertini@studenti.unipr.it

elenagiovanna.vittadini@unicam.it

eleonora.carini@unipr.it

A fibre syrup for the sugar reduction in fruit filling for bakery application

Alessandro Carcelli[1][3], Anna Albertini[1], Elena Vittadini[2], Eleonora Carini[1]*

[1] Department of Food and Drug, University of Parma, Parco Area delle Scienze 47/a, 43124 Parma, Italy

[2] School of Biosciences and Veterinary Medicine, University of Camerino, via Gentile III da Varano, 62032 Camerino, Macerata, Italy (current address)

[3]HI-FOOD S.p.A., Parco Area delle Scienze Pad. 27, 43124, Parma, Italy

* **Corresponding author**

E-mail address: eleonora.carini@unipr.it

address: Parco Area delle Scienze, 47/a, 43122 Parma, Italy

phone: +039 0521 906520

e-mail address of each author:

alessandro.carcelli1@studenti.unipr.it

anna.albertini@studenti.unipr.it

elenagiovanna.vittadini@unicam.it

eleonora.carini@unipr.it

Field Code Changed

Abstract

Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of *Cicer arietinum* seed) has been used to formulate reduced-sugar fruit fillings. Three reduced-sugar (by 30, 50 and 70%) recipes were developed starting from a standard formulation, in order to reach the "reduced in sugar" and "high in fibre" label claims. Physicochemical and sensory properties of the fruit fillings were assessed during 180 days of storage at two different temperatures (5°C and 25°C). Increased firmness, adhesiveness, consistency coefficient (K, flow behaviour), bake stability and colour differences have been observed in reformulated recipes with increasing fibre syrup content if compared to the control. Storage decreased bake stability and induced darkening of the product in all samples. 30% sugar-reduced filling were the most appreciated by consumers, and not distinguishable from the control. Overall results confirmed the syrup technological functionality when used to obtain a 30% sugar-reduction.

Keywords: Fruit filling, sugar reduction, fibre syrup, dietary fibre.

1. Introduction

In Europe, the estimated daily energy intake from sugar ranges between 15-21% in adult and between 16%-26% in children of the total energy intake (Azaïs-Braesco et al., 2017). These values are not in line with the World Health Organization (WHO) guidelines (World Health Organization, 2015) which recommends a sugar intake < 10% of the total energy intake; high levels are related to health problems as obesity, diabetes, and dental caries (Schwingshackl et al., 2017; Te Morenga et al., 2012; Touger-Decker & van Loveren, 2003). Awareness campaigns from health institutions and governments are informing consumers on the adverse effect of a high sugar diet. As a result, the request of reduced-sugar products on the market is increasing (FIE Global, 2020).

To fulfil a high-quality demand, food technologists are called to a complex challenge namely the replacement of the several quality and technological roles of sugar in food. Among the strategies proposed to reduce sugar in foods (Hutchings et al., 2019), the use of sugar substitutes is considered the most appropriate and viable in an industrial context (Hutchings et al., 2019). Sugar sweetness can be nowadays easily replaced using non-caloric sweeteners. On the contrary, the replacement of the sugar bulking effect with a proper ingredient remains difficult, especially for high sugar content products as jam, jelly, fruit filling in which sugar can be up to 60% of the product.

Technological functionalities of sugar substitutes should also satisfy the more and more increasingly consumer request for clean label ingredients (Asioli et al., 2017; Osborn, 2015). Ingredients able to simultaneously satisfy both the technological requirement and the clean label standard are of great interest. Dietary fibres are easily recognisable and positively accepted by the consumers (Dhingra et al., 2012), and they have been used either as bulking agents or as nutritional improvers (Buttriss, 2017; Shinwari & Rao, 2020).

In the frame of high sugar foods, bakery products which contain fruit-based filling are a growing sale sector (Cropotova et al., 2016). Fruit filling are mainly based on sugar, water, fruit puree/jam, flavour, and thickening agent (Wei et al., 2001). Despite the high sugar content of this food preparation, very few researchers worked on its sugar reduction; it has been reported the use of polydextrose (E1200) that allowed to obtain similar structures between reduced- and full- sugar products (Agudelo et al., 2015a; Agudelo et al., 2015b).

A commercial fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of *Cicer arietinum* seed) was previously characterized and tested as sugar replacer in cookies and ripple sauces with encouraging results (Carcelli, Alberti et al., 2021; Carcelli, Suo et al., 2021).

In this work, same commercial fibre syrup was tested as buking agent ingredient to develop reduced-sugar fruit filling formulations. Fruit fillings with different reduced-sugar levels were developed and characterised for their physicochemical and sensory properties at 5°C and 25°C for a storage period of 180 days to replicate the typical storage condition of the product in the industrial context.

2. Materials and methods

2.1 Materials

A fibre syrup (MELTEC®) was obtained from HI-FOOD S.p.A. (Parma, Italy). It is a clean label ingredient, which does not impart sweetness, with a consistency like honey, a gold brownish colour. Its dietary fibre content is ≈ 66% [(g fibre/100 g sample), High Molecular Weight Dietary Fiber and Low Molecular Weight Dietary Fiber (AOAC method 2009.01)], with a sugar content < 1.0% (g sugar/100 g sample), and a moisture content ≈ 25% (g water/100 g sample). The commercial fiber syrup was also characterized in terms of Brix degrees (portable refractometer HB 95, Lega Italy, Ravenna, Italy), water activity at 25°C (a_w, Aqualab 4 TE, Decagon Devices Inc., Pullman, WA, USA), pH (potentiometer pH7+DHS Food, XS Instruments, Modena, Italy) and colour. Colour analysis was performed using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan) equipped with a standard illuminant D65 and a 10°position of the standard observer. According to CIE Lab system, L* [0 (black) and 100 (white)], a* (–a*= greenness and + a*=redness) and b* (–b*= blueness and + b*= yellowness) parameters were measured. At least, three measurements were taken for each analysis.

Other ingredients used in the fruit filling recipes were: low-methoxyl (LM) pectin Classic AB 902 (Herbstreith&Fox KG, Werder, Germany), glucose syrup 60 dextrose equivalent DE “Glucoplus 361” (Uniglad Ingredienti, Cuneo, Italy), tricalcium citrate (Giusto Faravelli, Milano, Italy), potassium sorbate (Giusto Faravelli, Milano, Italy), crystalline sucrose (British sugar, Peterborough, UK), apricot jam (Rogelfrut, Cuneo, Italy), citric acid (Brenntag, Milano, Italy), apricot flavour NATLQ10989 (Internation Taste Solution, Newbury, UK).

2.2 Fruit filling preparation

Full-sugar (FS) and reduced-sugar (RS) fruit filling recipes, based on industrial recipe, are shown in Table 1. RSs were formulated replacing all the glucose syrup and increasing level of crystalline sucrose with fibre syrup in a 1:1 weight ratio. The replacement of sugar was designed in order to achieve its reduction by 30% (RS30), 50% (RS50) and 70% (RS70). All fruit filling samples were produced using a bowl chopper (Polyfunctional QB 8-3, Roboqbo, Bologna, Italy). As a first production step, LM pectin was mixed with crystalline sucrose in a 1:5 ratio, the mixture obtained was then dissolved in half of the water present in the recipe and pre-heated at 80°C with a blender (Minipimer MQ5035, Braun, Germany) at 13500 rpm for 5 min. In parallel, the other ingredients as crystalline sucrose, tricalcium citrate, glucose syrup or fibre syrup (for RS recipes), apricot jam and the remaining water in which the potassium sorbate was previously dissolved, were added together in the bowl chopper. The ingredients were subsequently mixed at 500 rpm and subjected to a heat treatment at 75°C until reaching 73 °Brix. Subsequently, the pre-mix of LM pectin and crystalline sucrose was added to the bowl chopper continuing the mixing process at 500 rpm at 90°C under vacuum (1 bar) to concentrate the preparation at 72 °Brix. Afterwards, the citric acid dissolved in few drops of water and the liquid apricot flavouring were added checking the pH until reaching a value of 3.6. As a final step, the product was cooled under vacuum (1 bar) at 800 rpm until reaching 65°C. The filling was transferred into plastic container to be analysed after cooling to RT (t0) or stored at 25°C or 5°C for analysis after 30, 60 and 180 days (t30, t60, t180). Filling formulations were characterized during storage both at 5°C and 25°C to verify their quality in different and frequent storage and consuming conditions as raw materials or components in final products.

Two batches of product for each formulation were produced in two different days.

2.3 Fruit filling characterisation

2.3.1 Nutritional profile

Macronutrient profile of FS and RSs was calculated using the European Institute of Oncology database (IEO-DBA, 2020). Energy (kJ and kcal) was obtained multiplying all macronutrients for their energy factors cited in the EU Regulation on labelling of food products (Regulation (EU) No 1169/2001).

2.3.2 °Brix and pH

°Brix of filling was measured using a refractometer HB 95 (Lega Italy, Ravenna, Italy) while pH with a potentiometer pH7+ DHS Food (XS Instruments, Modena, Italy). At least three measurements were taken at 25°C for each formulation for a total of six determinations.

2.3.3 Water activity and moisture content

Water activity was measured at 25 °C with an Aqualab 4 TE (Decagon Devices Inc. WA, USA). Moisture content (MC, g of water/100 g of sample) was measured by weight loss by drying in a forced-air oven (M120-TBR, MPM Instruments Srl, Milano, Italy) at 70 °C to constant weight.

At least three measurements were taken for each formulation for a total of six determinations at each storage time.

2.3.4 Textural and rheological properties

Texture properties were determined using TA.XT2 Texture Analyzer (Stable Micro Systems, Godalming, UK) equipped with a P/20 probe. A cylindrical container (58 X 70 mm) was completely filled with the product which it was subjected to a penetration test (50% strain at a rate of 0.8 mm/s). Firmness (peak force, N) and adhesiveness (negative area, N mm) were determined. Five measurements were taken for each batch for a total of ten determinations at each formulation and storage time.

A controlled stress rheometer (MCR 702 twin drive, Anton Paar, Graz, Austria) operating at 25°C with a 50 mm diameter plate-plate geometry and a gap of 1 mm was used to study the flow behaviour of fruit fillings. Before each analysis, the exposed surface of samples was protected with paraffin oil, besides the samples were allowed to rest for 3 minutes until axial force reached ~0 N. Flow curves were obtained increasing shear rates from 1 to 100 s^{-1}. Power law equation was used to fit the experimental data, according to:

$$\sigma = K\gamma^{n}$$

where σ is the shear stress (Pa), γ is the shear rate (s^{-1}), K is the consistency coefficient ($Pa{*}s^{n}$) and n the non-Newtonian index (dimensionless).

Three measurements were performed for each batch for a total of six determinations for each formulation.

2.3.5 Colour

Colour was measured using the method reported by Carcelli and co-workers (Carcelli et al., 2020) using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan) equipped with a standard illuminant D65 and a 10° position of the standard observer. The results were expressed in accordance with the CIE Lab system; ΔE was calculated using FS as a reference (Carcelli et al., 2020). Ten determinations were performed for each batch for a total of twenty determinations for each formulation.

2.3.6 Syneresis and bake stability

Syneresis was measured as described by Cropotova and co-workers (Cropotova et al., 2009). Samples of 5 g (F_0) were transferred into a 50 ml falcon tube, sealed with plastic cap and centrifuged at 3000 rpm for 20 min (centrifuge 5910R, Eppendorf, Milan, Italy). The weight of the supernatant fraction (F_1) was measured and grade of syneresis was calculated as percentage (%) = $(F_1/F_0)*100$. Three replicates for each batch for a total of six determinations for each formulation were carried out.

Bake stability was evaluated following Young and colleagues with slight modifications (Young et al., 2003). Fruit filling samples of 10 g were placed into a circular mould (∅ 35 mm) on a 7x7 cm layer of short crust. On the circular sample obtained, 4 points have been marked on the external part to measure the pre- and post-baking (200° C, 10 min, 903.008.05, IKEA, Leida, Netherlands) diameter. Bake stability percentage (B.S.%) has been calculated according with:

$$B.S.\% = 100 - \left[\left(\frac{\varnothing pb - \varnothing bb}{\varnothing bb}\right) * 100\right]$$

where $\varnothing pb$ is diameter post baking while $\varnothing bb$ is diameter before baking.

Three measurements were performed for each batch changing the position of the short crust in the oven, for a total of six determinations for each formulation.

2.3.7 Sensory analysis

Sensory analysis of filling samples was realized using both an acceptability and a rapid profiling check-all-that-apply (CATA) test performed on samples immediately after production and after 60 and 180 days (t0, t60, t180). The tests were performed to 50 untrained judges using the method reported by Carcelli and co-workers (Carcelli et al., 2020). For CATA test the attributes random reported in the questionnaire were: pleasant colour, unpleasant colour, opaque, orange, brown, shiny, acid, bitter, sweet, very sweet, slightly sweet, good taste, bad taste, mediocre taste, vegetal taste, apricot taste, good aftertaste, bad aftertaste, pleasant consistency, unpleasant consistency, melty, jelly, sticky, fluid, sandy. Data were collected as the times each attribute was selected for each sample.

2.3 Statistical analysis

Data were processed with a three-way ANOVA using three fixed factors: recipe (R), storage time (St) and storage temperature (ST). The evaluation of single factor and their interactions in the variability of each parameter was obtained with the partition of total variance of sum square (SS%). Significant differences ($p \leq 0.05$) among different samples were assessed by one-way-analysis of variance (ANOVA) with a Duncan post-hoc test using an IBM SPSS statistical software (Version

24.0, SPSS Inc., Armonk, New York, USA). The contingency table of CATA dataset was obtained on the basis of samples and attributes. A correspondence analysis was performed to summarize the relationship between samples and attributes using Statistica software (Version.13.3, TIBCO Software Inc.).

3. Results and discussion

The high levels of sucrose and glucose syrup used by fruit fillings manufacturers strongly affect products overall quality. In this study, all the glucose syrup and increasing level of crystalline sucrose have been partially replaced with a commercial fibre syrup, in an attempt to develop products with reduced-sugar content. The physico-chemical characterization of the semi-solid fibre indicated that the fibre syrup had ~75 Brix, water activity ~0.88 and pH of ~6.4. As for fiber syrup colour, L* resulted ~23, a* ~0.34 and b* ~3.34. The values of the coordinates ~~a* and b* coordinates~~ indicated the marked presence of redness and yellowness tones, thus confirming the brownish colour.

FS and RSs samples were prepared keeping constant pH and °Brix to replicate the industrial process. In particular, pH = 3.6 ± 0.1 and °Brix = 72 ± 1 were reached in all samples increasing the citric acid content and prolonging (where necessary) the cooking time, respectively. pH and °Brix were also monitored throughout the entire storage time (data not showed) indicating significant but slight changes and remaining in the desired range.

3.1 Nutritional label information

Pillar of the study was the development of a filling formulation with an improved nutritional profile in terms of lower sugar and higher dietary fibre contents, if compared with a standard filling formulation. The nutritional labels of FS and RSs are reported in Table 2.

Energy decreased remarkably with the increase of the fibre syrup moving from 964 KJ/230 Kcal of FS to 831 KJ/198 Kcal, 724 KJ/173 Kcal and 620 KJ/148 Kcal of RS30, RS50 and RS70, respectively.

The energy decrease was associated to the decrease of the carbohydrates in favour of the dietary fibres which have a lower energy conversion factor as indicated in the EU Regulation on labelling of food products (Regulation (EU) No 1169/2001). Moreover, RSs presented a sugar content reduced by 30% (RS30, from 55.8 g/100 g to 39 g/100 g), 50% (RS50, from 55.8 g/100 g to 27.5 g/100 g) and 70% (RS70, from 55.8 g/100 g to 17 g/100) if compared with FS. A slight increase of protein content was observed for RS50 and RS70 (respectively 0.6 g/100 g and 0.9 g/100 g) due to the increase of the fibre syrup in the formulation which intrinsically has a low amount of residual protein content. The increase of the fibre syrup led to an increase in the fibre content in the recipe from 1 g/100 g of FS to 15 g/100 g, 22.5 g/100 g and 30 g/100 g for RS30, RS50 and RS70, respectively. The decrease of sugar and the increase of fibre contents would allow to label all the RSs with the double nutritional claims "reduced in sugar" and "high in fibre" based on the EU regulation on nutritional and health claims (Regulation (EC) No 1924/2006).

3.2 Physico-chemical characterization

Product stability at rheological, chemical and microbiological level is strongly related to water activity (a_w) and moisture content (MC). Both parameters for all samples during storage are reported in Table 3 while the statistical outputs can be found in Table 4.

MC was affected by recipe (R) increasing with the decrease of sugar in the recipe (from ≈20% in FS to ≈23% in RS70 at t0). Similarly, a_w was highly affected by R showing an increase with the decrease of sugar moving from ≈0.80 in FS to ≈0.87 in RS70. Similar trends were noticed at all storage temperatures and times. These results were related to the water content (≈25% g water/100 g sample) of the fibre syrup used to partially replace sugar and/or to its different interaction with water than those developed by sugar. Indeed, sugar is highly hygroscopic and has higher capacity than fibre to bind water thanks to the higher amount of available free hydroxyl group compared to long chain polysaccharides. The increase of a_w and MC when sugar was replaced by vegetable fibres was previously reported in studies conducted on cakes, muffin and fruit jellies (Milner et al., 2020; Riedel et al., 2015; Zahn et al., 2013). However, the increase of both parameters does not affect product microbiological stability because the product is acidic (pH ~3.6) and it is stabilised with a hot filling process. The use of fiber syrup as sugar substitute in non-acidic products should envisage acid regulation to ensure microbiological safety. MC was affected also by St which slightly fluctuated during storage probably due to a macroscopic water redistribution in the product. The storage temperature did not affect neither the moisture content and the water activity with only a slightly significant difference for FS and RS30 at t60.

Fruit fillings rheological properties were assessed using both empirical and fundamental techniques in order to verify agreement between the two analytical approaches providing useful information to those food industries able to implement only cheaper and easier rheological methods. Fillings' firmness and adhesiveness parameters (Figure 1) aimed to give some information related to the mouthfeel of the product which is an important quality characteristic of semi-solid foods as filling. These food materials indeed shall not be chewed and their texture features are directly perceived in the mouth by tongue receptors (Agudelo et al., 2015a). Three-way ANOVA (Table 4) highlighted that firmness and adhesiveness were primarily affected by R with a significant increase of both parameters with the sugar decrease in the recipes. The increase of firmness and adhesiveness was likely affected by the increase of the fibre syrup which bulking effect strongly impacted on the overall structure. This phenomenon is probably due to the interactions among the polysaccharide long chains present in the syrup which probably affected the macrostructure. At t30, t60 and t180, FS, RS30 and RS50 had comparable firmness and adhesiveness while RS70 was harder and more adhesive than all other samples.

Flow properties play a fundamental role in the quality characteristics of filling. Its fluidity and structure may modulate the flavour perception in the mouth and therefore influence consumer acceptability; moreover, pumping and baking phase at industrial level may be strongly affected by a change in system fluidity (Agudelo et al., 2015a; Razak et al., 2018; Wei et al., 2001). Flow curves fitting allowed to calculate the non-Newtonian index (*n*, data not showed) and the consistency coefficient (K, Table 4, Figure 2).

n index of fillings fell between 0.33-0.40, characterising the product as pseudo plastic fluid ($n<1$), as previously reported in fruit filling (Nalawade et al., 2017; Wei et al., 2001). *n* index was more affected by St with only slight significative variation during storage (Table 4). K was instead strongly influenced by R showing a significantly increase with the reduction of sugar. Higher K at all storage times and temperatures was observed for RS70 if compared to other samples. A good positive relation (r^2 = 0.96) was found between firmness and K, probing accordance between empirical and fundamental rheological analysis. Overall, the fibre syrup used in this work increased firmness and K when used to reduce sugar above 30%. On the contrary, polydextrose (E1200) was found to marginally affect the rheological properties of fruit filling when used to completely replace sugar (Agudelo et al., 2015b).

Consumer acceptability is strongly influenced by the colour which is one of the most important appearance factors, influencing also the flavour perception and the overall purchase decision (Pathare et al., 2013). The colour properties of fillings were therefore analysed (Table 5).

Colour was most affected by St (Table 4): a significant decrease of all colour parameters was noticed at both storage temperatures in all samples (more pronounced in FS). A decrease of L^*, a^* and b^* during storage was observed also in previous studies on apricot (Touati et al., 2014) and strawberry jam (Wicklund et al., 2005). The darkening of jam products during storage has been associated to the fruit anthocyanidins degradation. Anthocyanidins originate from anthocyanins degradation which occurs during thermal and mechanical production steps. Anthocyanidins are less stable than anthocyanins to light and oxygen and consequently more prone to browning reactions (Wicklund et al., 2005). .

Colour was less affected by R (Table 4) where in fresh products a significative decrease of all parameters was noticed with the increase of the fibre syrup due to its intrinsic brownish colour. Colour changes as a function of St and R were also highlighted by the ΔE values (Table 5). However, it is important to remark that all the formulations studied did not contain any food colouring ingredients which could be included in the formulation in the industrial scale up in order to stabilise the product during storage and to counterbalance the presence of the fibre syrup.

Other fruit filling' quality features are the stability – preservation of the dimension at high temperature during baking (Agudelo et al., 2014; Young et al., 2003) and the absence of water syneresis as a migration of water from the fruit filling to the dough may lead to product inhomogeneity and stickiness (Cropotova et al., 2016). All filling formulations produced did not show water syneresis during storage. The absence of water syneresis also in the RSs in which MC and a_w were higher than in FS indicates that the fibre syrup had a positive technological role acting as stabilising ingredient.

Bake stability results (Table 6) indicated its addiction by St showing a decrease during storage in all samples. Moreover, only at t0, formulations containing the fibre syrup showed a significantly increase of their bake stability index if compared with FS highlighting an improvement of this quality indicator in the fresh product.

3.3 Sensory analysis

All the fruit fillings were considered acceptable by the consumers (overall acceptability scores higher than 5 in all cases) with FS and RS30 considered the most preferred (score ≈7) (Figure 3). The lowest scores were attributed to RS70, in particular for consistency which was evaluated with a score < 5 indicating a worsening of the fruit filling structure probably due to its higher firmness, adhesiveness and K compared to the other formulations. No significative differences for sensory attributes were registered during storage. These findings are encouraging considering that the product sensory stability for long lasting shelf-life is a relevant quality feature. A better elucidation of the fillings' consumers perception was assessed using a CATA test. The two dimensions of the factor plane representing the CATA test conducted at t0 (Figure 4) explained ≈93% of the variance, with dimension 1 explaining ≈80% and dimension 2 explaining ≈13%. IDEAL fruit filling was described as fluid, pleasant consistency, melty, sweet, apricot taste, good aftertaste, good taste. Attributes as "melty", "sweet" and "fruity" were also found in the IDEAL filling in the study of (Agudelo et al., 2015b). FS and RS30 were described by similar attributes: pleasant colour, orange, shiny, very sweet. On the opposite, RS50 and RS70 were characterised by negative attributes as jelly, vegetal taste, mediocre taste, sticky and unpleasant colour (RS50), and opaque, acid, slightly sweet, bad aftertaste, unpleasant consistency, brown, bad taste, sandy and bitter (RS70). The negative attributes related to consistency for RS50 and RS70 highlighted that the use of the syrup in high amount led to a detrimental effect on product texture increasing the "jelly" perception which is the opposite of the fluid attribute applied for the IDEAL product. Consumers' appreciation for the fruit filling fluid consistency was previously reported (Agudelo et al., 2015b). Overall, RS30 was the most appreciated reduced-sugar formulation based on both acceptability and CATA test, particularly for its texture properties. No remarkably differences on samples attributes were noticed during storage confirming the results of the acceptability test.

4. Conclusions

"Sugar reduced" and "high in fibre" claims could be used to label reformulated fruit fillings by means of the use of a syrup based on chickpea and maize fibre as sugar replacer. The use of the syrup increased the a_w, MC as well as firmness, adhesiveness, K consistency coefficient and bake stability, while decreased the colour coordinates L^*, a^*, b^*. Storage time mainly affected the colour and the bake stability of all fruit fillings while the storage temperature presented a little or negligible effect on all studied parameters. When sugar was reduced by 30% the overall physicochemical and sensory properties of the reformulated fruit filling were found to be similar to the full-sugar counterpart.

The use of the fibre syrup as clean label ingredient was found to be a valuable ingredient on a technological standpoint, allowing to improve the nutritional profile of the product and to partially replace the bulking agent role of sugar.

Acknowledgments

The Authors would like to thank Francesca Petrelli for carrying out part of the experimental work.

Conflict of interests

AC was involved in the research as Industrial PhD student. Universities involved in this research have not received any funding.

Ethical guidelines statement

All judges were previously informed about the scope of the research and of its non-commercial purpose, as well as their anonymous and voluntary participation. Moreover, judges were informed of the composition of the fruit fillings to exclude any allergic subject. Judges were also informed about the possible use of the data raised by the study for any scientific or informative communication.

References

1. Agudelo, Alejandra, Varela, P., & Fiszman, S., 2015. Fruit fillings development: A multiparametric approach. LWT – Food Sci. Technol., 61(2),564-572.
2. Agudelo, A., Varela, P., & Fiszman, S., 2015. Methods for a deeper understanding of the sensory perception of fruit fillings. Food Hydrocolloids 46 (160-171).
3. Agudelo, Alejandra, Varela, P., Sanz, T., & Fiszman, S., 2014. Formulating fruit fillings. Freezing and baking stability of a tapioca starch-pectin mixture model. Food Hydrocolloids, 40, 203-213.
4. Asioli, D., Aschemann-Witzel, J., Caputo, V., Vecchio, R., Annunziata, A., Næs, T., & Varela, P., 2017. Making sense of the "clean label" trends: A review of consumer food choice behavior and discussion of industry implications. Food Res. Int., 99, 58-71.

5. Azaïs-Braesco, V., Sluik, D., Maillot, M., Kok, F., & Moreno, L. A., 2017. A review of total & added sugar intakes and dietary sources in Europe. Nutr. J., 16(1), 1-15.
6. Buttriss, J. L., (2017). Challenges and opportunities in the use of low-energy sugar replacers. Nutr. Bulletin, 42(2), 108-112.
7. Carcelli, A., Albertini, A., Vittadini, E., & Carini, E., 2021. Strawberry ripple sauce: A semi-solid fibre syrup to reduce sugar content. Int. J. Gastron. Food Sci, 100411.
8. Carcelli, A., Crisafulli, G., Carini, E., & Vittadini, E., 2020. Can a physically modified corn flour be used as fat replacer in a mayonnaise?. Eur. Food Res. Technol., 246(12), 2493-2503.
9. Carcelli, A., Suo, X., Boukid, F., Carini, E., & Vittadini, E., 2021. Semi- solid fibre syrup for sugar reduction in cookies. Int. J. Food Sci. Tech., 56(10), 5080-5088.
10. Cropotova, J., Tylewicz, U., Dellarosa, N., Laghi, L., Romani, S., & Dalla Rosa, M., 2016. Effect of freezing on microstructure and degree of syneresis in differently formulated fruit fillings. Food Chem., 195,71-78.
11. Dhingra, D., Michael, M., Rajput, H., & Patil, R. T., 2012. Dietary fibre in foods: A review. J. Food Sci. Tech. 49(3), 255-266.
12. FIE Global, 2020. Delivering taste and texture in food and beverage, Available:https://www.figlobal.com/content/dam/Informa/figlobal/fieurope/en/2020/documents/HLN20FIE-GM-Delivering-taste-and-texture-in-food-and-beverages.pdf (accessed 19 December 2020).
13. Hutchings, S. C., Low, J. Y. Q., & Keast, R. S. J., 2019. Sugar reduction without compromising sensory perception. An impossible dream? Crit. Rev. Food Sci., 59(14), 2287-2307.
14. European Institute of Oncology, 2015. Food composition database for epidemiological studies in Italy [Online]. Available: http://www.bda-ieo.it [24 July 2020].

15. European Union, 2006. Regulation No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. Official Journal of the European Union, L404, 9-25.
16. European Union, 2011. Regulation No N 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. Official Journal of the European Union, L304, 18-63
17. McCleary, B. V., De Vries, J. W., Rader, J. I., Cohen, G., Prosky, L., Mugford, D. C., ... & Okuma, K., 2010. Determination of total dietary fiber (CODEX definition) by enzymatic-gravimetric method and liquid chromatography: Collaborative study. Journal of AOAC international, 93(1), 221-233. doi.org/10.1093/jaoac/93.1.221
18. Milner, L., Kerry, J. P., O'Sullivan, M. G., & Gallagher, E., 2020. Physical, textural and sensory characteristics of reduced sucrose cakes, incorporated with clean-label sugar replacing alternative ingredients. Innov. Food Sci. Emerg. 59, 102235.
19. Nalawade, T., Chavan, R. S., & Joshi, A., 2017. Rheological Characterization of Fruit Fillings, in: Meghwal, M., Goyal M.R., Chavan, R.S., (Eds.), Dairy Engineering: Advanced Technologies and Their Applications, Apple Academic Press, pp. 37-52.
20. Osborn, S., 2015. Labelling relating to natural ingredients and additives. In Advances in Food and Beverage Labelling: Information and Regulations (pp.207-221).
21. Pathare, P. B., Opara, U. L., & Al-Said, F. A. J., 2013. Colour Measurement and Analysis in Fresh and Processed Foods: A Review. Food Bioprocess Tech., 6(1), 36-60.
22. Razak, R. A., Karim, R., Sulaiman, R., & Hussain, N., 2018. Effects of different types and concentration of hydrocolloids on mango filling. Int. Food Res. J. 25(3),1109-1119.
23. Riedel, R., Böhme, B., & Rohm, H., 2015. Development of formulations for reduced-sugar and sugar-free agar-based fruit jellies. Int. J. Food Sci. Tech., 50(6), 1338-1344.
24. Schwingshackl, L., Hoffmann, G., Lampousi, A. M., Knüppel, S., Iqbal, K., Schwedhelm, C., Bechthold, A., Schlesinger, S., & Boeing, H., 2017. Food groups and risk of type 2 diabetes

mellitus: a systematic review and meta-analysis of prospective studies. Eur. J. Epidemiol., 32(5), 363-375.

25. Shinwari, K. J., & Rao, P. S. (2020). Rheological and physico- chemical properties of a reduced- sugar sapodilla (Manilkara zapota L.) jam processed under high- hydrostatic pressure. J. of Food Process Eng., *43*(6), e13388.

26. Te Morenga, L., Mallard, S., & Mann, J., 2012. Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. BMJ 7492 1-25.

27. Touati, N., Tarazona-Díaz, M. P., Aguayo, E., & Louaileche, H., 2014. Effect of storage time and temperature on the physicochemical and sensory characteristics of commercial apricot jam. Food Chem., 145, 23-27.

28. Touger-Decker, R., & van Loveren, C., 2003. Sugars and dental caries. The American J. of Clinical Nutr. 78(4), 881S-892S.

29. Wei, Y. P., Wang, C. S., & Wu, J. S. B., 2001. Flow properties of fruit fillings. Food Res. Int., 34(5), 377-381.

30. Wicklund, T., Rosenfeld, H. J., Martinsen, B. K., Sundfør, M. W., Lea, P., Bruun, T., Blomhoff, R., & Haffner, K., 2005. Antioxidant capacity and colour of strawberry jam as influenced by cultivar and storage conditions. LWT – Food Sci. Technol., 38(4), 387-391. doi.org/10.1016/j.lwt.2004.06.017.

31. World Health Organization, 2015. Guideline: sugars intake for adults and children. Geneva: World Health Organization.

32. Young, N. W. G., Kappel, G., & Bladt, T., 2003. A polyuronan blend giving novel synergistic effects and bake-stable functionality to high soluble solids fruit fillings. Food Hydrocolloids 17(4), 407-418.

33. Zahn, S., Forker, A., Krügel, L., & Rohm, H., 2013. Combined use of rebaudioside A and fibres for partial sucrose replacement in muffins. LWT – Food Sci. Technol., 50(2), 695-701.

Table 1. Fruit filling recipes (% wt).

	FS	RS30	RS50	RS70
Sucrose	32	30.6	19.3	8.3
Glucose syrup	20	-	-	-
MELTEC®	-	21.4	32.7	43.7
Water	26.9	26.8	26.75	26.72
Apricot jam	20	20	20	20
Pectin	0.8	0.8	0.8	0.8
Citric acid	0.14	0.24	0.29	0.32
Tricalcium citrate	0.08	0.08	0.08	0.08
Potassium sorbate	0.05	0.05	0.05	0.05
Apricot flavour	0.03	0.03	0.03	0.03

FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 2. Nutritional composition based on Reg EU 1169/2011 of fruit fillings at different sucrose content (g/100g).

	FS	**RS30**	**RS50**	**RS70**
Energy (kJ)	964	831	724	620
Energy (kcal)	230	198	173	148
Fat	0	0	0	0
-of which saturated	0	0	0	0
Carbohydrates	57.0	41	30.5	20
-of which sugars	55.8	39	27.5	17
Fibre	1.0	15.0	22.5	30.0
Protein	0	0	0.6	0.9
Salt	0	0	0	0

FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 3. Moisture content (MC), water activity (a_w) of fruit filling at different sugar content during storage (t0, t30, t60, t180) at different temperatures (5°C, 25°C).

		Moisture content (MC) g H_2O/ 100 g of sample			
		t0	t30	t60	t180
5 °C	FS	20.50 ±0.02 bB	22.50 ±0.01 bA	23.50 ±0.01 bA*	22.83 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.83 ±0.01 abA	24.17 ±0.01abA*	23.83 ±0.01 abA
	RS50	22.50±0.01 aB	24.50±0.02 aA	25.00±0.02 aA	24.67±0.02 aA
	RS70	23.00±0.01aB	23.67±0.01 abB	25.00±0.01 aA	23.67±0.01 abB
25° C	FS	20.50 ±0.02 bB	22.00 ±0.01 bA	22.83 ±0.01 bA*	22.33 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.33 ±0.01 aAB	23.67 ±0.01 bA*	23.83 ±0.01 aA
	RS50	22.50±0.01 aB	24.33 ±0.01 aA	24.67 ±0.01 aA	24.00 ±0.01 aA
	RS70	23.00±0.01aB	23.67±0.01 aB	24.67±0.01 aA	23.83±0.01 aAB
		Water activity (a_w)			
		t0	t30	t60	t 180
5 °C	FS	0.800 ±0.010 dA	0.801 ±0.014 dA	0.805 ±0.007 dA	0.794 ±0.004 dA
	RS30	0.836 ±0.007 cAB	0.836 ±0.009 cAB	0.842 ±0.004 cA	0.832 ±0.003 cB
	RS50	0.861 ±0.005 bA	0.858 ±0.005 bA	0.864 ±0.005 bA	0.857 ±0.008 bA
	RS70	0.874 ±0.003 aA	0.874 ±0.002 aA	0.876 ±0.003 aA	0.866 ±0.003 aB
25° C	FS	0.800 ±0.010 dA	0.798 ±0.009 dA	0.804 ±0.010 dA	0.784 ±0.004 dB
	RS30	0.836 ±0.007 cA	0.833 ±0.009 cA	0.839 ±0.003 cA	0.824 ±0.006 cB
	RS50	0.861 ±0.005 bA	0.857 ±0.004 bA	0.858 ±0.010 bA	0.846 ±0.010 bB
	RS70	0.874 ±0.003 aA	0.871 ±0.004 aA	0.875 ±0.003 aA	0.865 ±0.002 aB

All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample ($p \leq 0.05$), where the small letters due to the sugar content, capital letter due to the time of storage and * due to temperature of storage. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 4. Partition of the total variance of sum square (SS%) of each single factor (R: recipe, St: storage time; ST: storage temperature) and their interactions for each parameter studied. In brackets the significance ($p < 0.05$) of the influence of individual factors and their interactions.

	R	St	ST	R*St	R*ST	St*ST	R*St*ST
a_w	96.6 (0.00)	2.5 (0.00)	0.3 (0.00)	0.1 (0.90)	0.1 (0.71)	0.2 (0.04)	0.2 (0.89)
MC	45.6 (0.00)	45.7 (0.00)	1.3 (0.07)	5.8 (0.12)	0.4 (0.81)	0.6 (0.71)	0.6 (0.99)
Firmness	48.5 (0.00)	39.4 (0.00)	2.4 (0.00)	5.0 (0.00)	0.3 (0.63)	4.0 (0.00)	0.4 (0.98)
Adhesiveness	63.4 (0.00)	21.5 (0.00)	5.0 (0.00)	4.7 (0.00)	0.3 (0.51)	4.8 (0.00)	0.3 (0.98)
n	17.8 (0.00)	37.8 (0.00)	11.1 (0.00)	15.5 (0.82)	0.0 (0.00)	15.6 (0.00)	2.2 (0.82)
K	78.7 (0.00)	9.7 (0.00)	4.9 (0.00)	1.0 (0.83)	0.3 (0.65)	4.5 (0.00)	0.9 (0.89)
L*	25.9 (0.00)	64.6 (0.00)	1.6 (0.00)	5.7 (0.00)	0.2 (0.63)	1.7 (0.00)	0.3 (0.40)
a*	29.5 (0.00)	57.5 (0.00)	0.2 (0.05)	2.5 (0.00)	0.4 (0.01)	8.8 (0.00)	1.1 (0.00)
b*	30.7 (0.00)	55.6 (0.00)	4.4 (0.00)	5.3 (0.00)	0.4 (0.00)	3.3 (0.00)	0.3 (0.00)
Bake stability	2.9 (0.00)	85.0 (0.00)	2.2 (0.00)	5.1 (0.00)	1.6 (0.00)	1.1 (0.00)	2.1 (0.00)

Table 5. Color parameters of fruit fillings at different sugar content during storage (t0, t30, t60, t180) at different temperatures (5°C, 25°C).

		t0		t30				t60				t180			
				5°C		25°C		5°C		25°C		5°C		25°C	
			ΔE		*ΔE*		*ΔE*		*ΔE*		*ΔE*		*ΔE*		*ΔE*
FS															
	*L**	35.42 ± 1.70 aA		33.16 ± 1.27aB		33.71 ± 1.89aB		30.71 ± 1.35aC		30.58 ± 1.39aC		30.51 ± 1.16aC		28.48 ± 1.01abD	
	*a**	10.71 ± 1.28aA	-	8.44 ± 1.28aB	-	9.19 ± 1.91aB	-	6.53 ± 1.24aC	-	5.70 ± 1.53aC	-	6.36 ± 1.14aC*	-	4.87 ± 0.92aC*	-
	*b**	15.00 ± 2.40aA		11.80 ± 1.83aB		13.35 ± 2.72aB		8.50 ± 1.39aC		8.03 ± 1.85aC		8.27 ± 1.56aC		5.42 ± 0.99aD	
	ΔE	-		4.5		2.8		9.1		9.8		9.4		13.2	
RS30															
	*L**	32.40 ± 1.50bA		30.98 ± 0.42bB		30.86 ± 0.75bB		29.57 ± 0.78bC		29.43 ± 1.10bC		29.52 ± 1.24bC		27.89 ± 1.05abD	
	*a**	9.18 ± 1.78bA	5.3	7.66 ± 0.80bB	3.9	8.51 ± 1.59bA	5.2	5.25 ± 1.32bC	2.18	5.16 ± 1.94abB	2.4	6.88 ± 1.25aD*	1.25	4.10 ± 1.05aB*	1.6
	*b**	10.85 ± 2.02bA		8.71 ± 0.76bB		9.03 ± 1.34bB		7.16 ± 0.95bC		6.03 ± 1.50bC		7.70 ± 1.47aC		4.10 ± 0.79bD	
	ΔE	-		3.0		2.5		6.1		6.9		4.8		9.6	
RS50															
	*L**	31.76 ± 1.01bA		29.70 ± 0.54cB		29.71 ± 0.52cB		28.97 ± 0.4cC*		28.28 ± 0.37cC*		28.28 ± 0.85cD		27.74 ± 1.14bC	
	*a**	8.56 ± 1.36bA	6.8	6.07 ± 0.90cB*	6.3	6.76 ± 0.71cB*	7.8	4.10 ± 0.62cC	4.0	4.35 ± 1.15bcC	3.8	4.78 ± 0.95bC*	3.77	4.15 ± 1.59aC*	1.7
	*b**	9.65 ± 1.26bA		7.12 ± 0.91cB		7.10 ± 0.58cB		5.82 ± 0.64cC*		5.34 ± 0.48cC*		5.66 ± 1.04bC		4.11 ± 1.01bD	
	ΔE	-		4.1		3.7		6.5		7.0		6.5		8.1	
RS70															
	*L**	30.75 ± 1.12cA		30.26 ± 1.0cA*		29.53 ± 0.4cB*		28.52 ± 0.3cB*		28.17 ± 0.40cC*		28.42 ± 0.92cB		28.90 ± 2.2aBC	
	*a**	6.91 ± 1.00cA	9.2	5.51 ± 0.90cB	6.1	5.92 ± 0.57cB	8.5	3.74 ± 1.12cC	4.7	3.45 ± 0.39cC	4.8	4.13 ± 0.75bC*	4.38	2.50 ± 0.88bD*	3.4
	*b**	8.00 ± 0.69cA		7.25 ± 1.26cB		6.68 ± 0.53cB		5.42 ± 0.73cC*		4.60 ± 0.41cC		5.13 ± 0.78bC		3.06 ± 0.81cD	
	ΔE	-		1.7		2.0		4.7		5.5		4.6		6.9	

All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among samples ($p \leq 0.05$), where the small letters due to the sugar content, capital letter due to the time of storage and * due to temperature of storage. Vertically are reported ΔE associated to the reformulation while horizontally ΔE associated to the storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 6. Bake stability of fruit filling at different sugar content during storage (t0, t30, t60, t180) at different temperature (5°C, 25°C).

		Bake stability (%)			
		t0	t30	t60	t180
5 °C	FS	77.75 ± 0.10 bA	69.75 ± 0.12 aB	69.13 ± 0.05 aB	62.38 ± 0.09 aC
	RS30	81.58 ± 0.05 aA	75.54 ± 0.13 aB	68.63 ± 0.07 aC	60.71 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	74.04 ± 0.10 aB	71.29 ± 0.10 aB*	58.46 ± 0.08 aC
	RS70	85.04 ± 0.05 aA	76.04 ± 0.10 aB	69.67 ± 0.09 aC	60.21 ± 0.07 aD
25° C	FS	77.75 ± 0.10 bA	74.67 ± 0.11 aA	69.08 ± 0.08 aB	65.33 ± 0.10 aB
	RS30	81.58 ± 0.05 abA	76.71 ± 0.07 aB	69.13 ± 0.08 aC	63.46 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	76.25 ± 0.04 aB	65.29 ± 0.05 aB	56.54 ± 0.08 aB
	RS70	85.04 ± 0.05 aA	72.04 ± 0.08 aB	65.17 ± 0.08 aC	62.13 ± 0.09 aC

All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample ($p \leq 0.05$), where the small letters due to the sugar content, capital letter due to storage time and * due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Figure 1. Firmness and adhesiveness of fruit fillings at variable sucrose content during storage at different temperatures (black: 5°C, grey: 25°C). Different letters close to the bar indicated significative difference among sample ($p \leq 0.05$) where the small letters were due to the sugar content while capital letter to storage time, and * symbol represented the difference due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

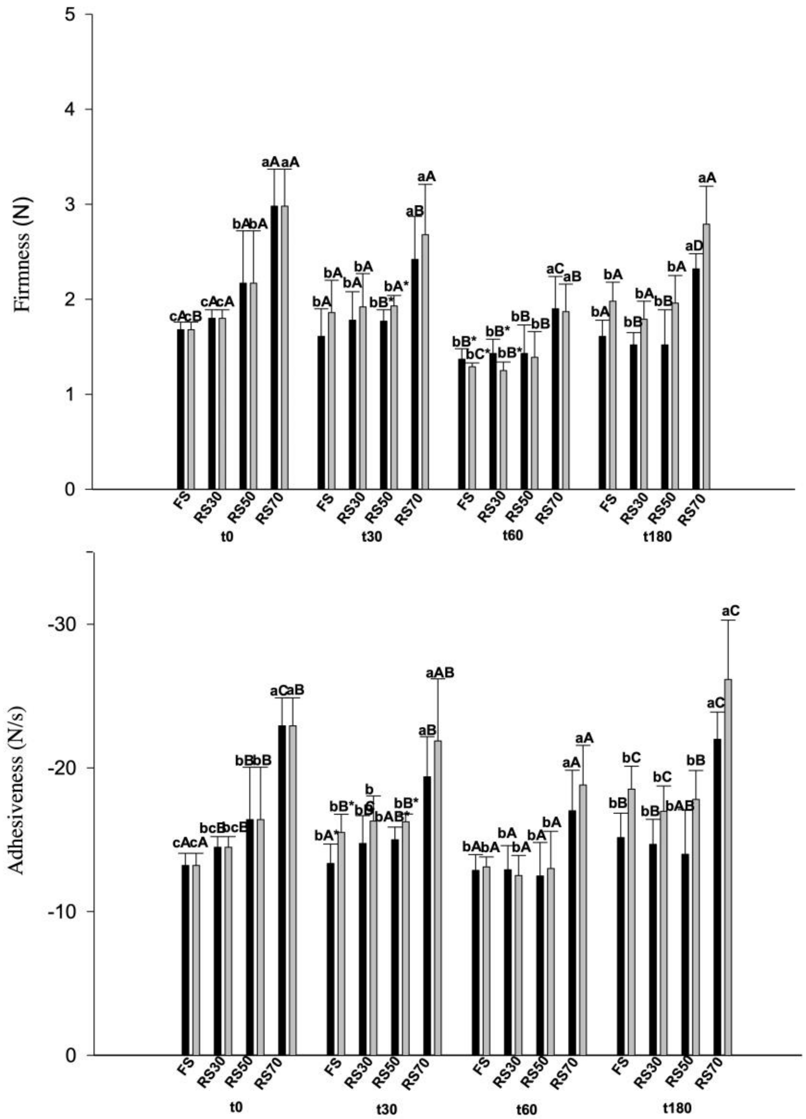


Figure 2. Consistency index of fruit fillings at variable sucrose content during storage at different temperatures (black: 5°C, grey: 25°C). Different letters close to the bar indicate significative difference among sample ($P \leq 0.05$) where the small letters due to the sugar content, capital letter due to storage time and * symbol due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

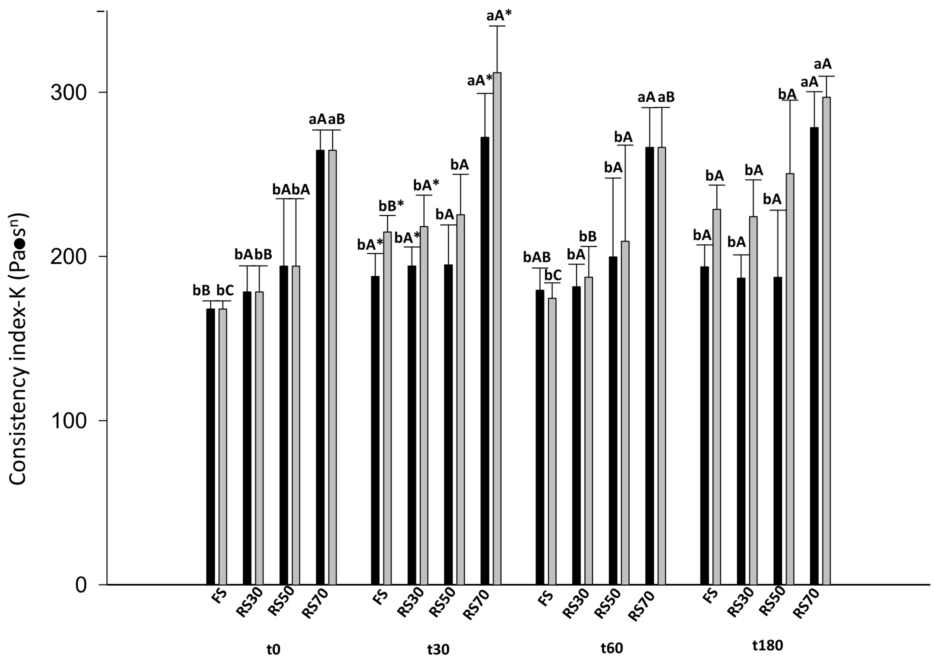


Figure 3. Sensory scores for consistency, taste, colour and overall acceptability of fruit filling at variable sucrose content. Different letters close to the bar indicate significative difference among sample ($p \leq 0.05$) where the small letters due to the sugar content, capital letter due to storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

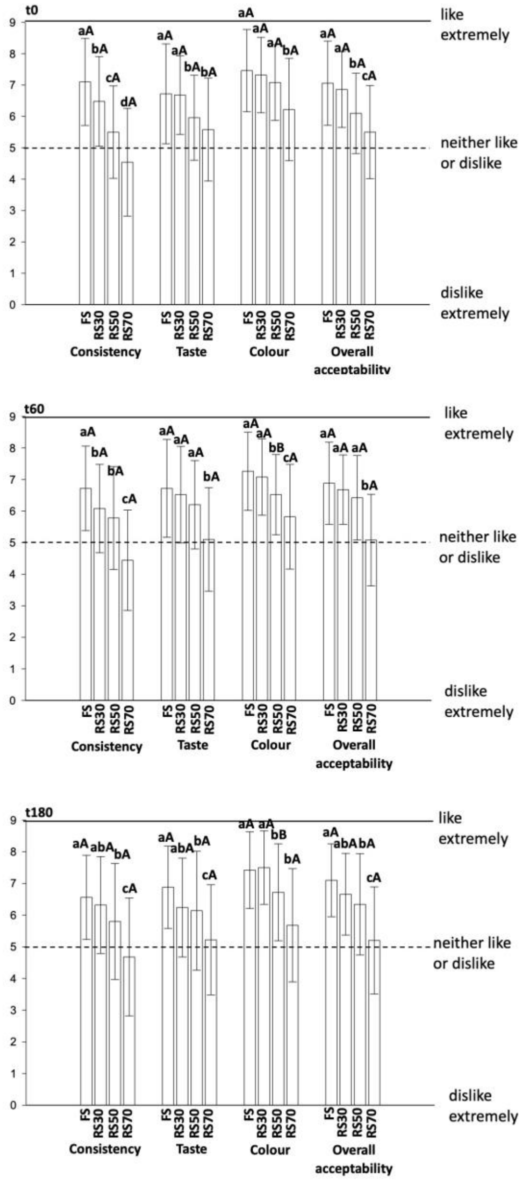
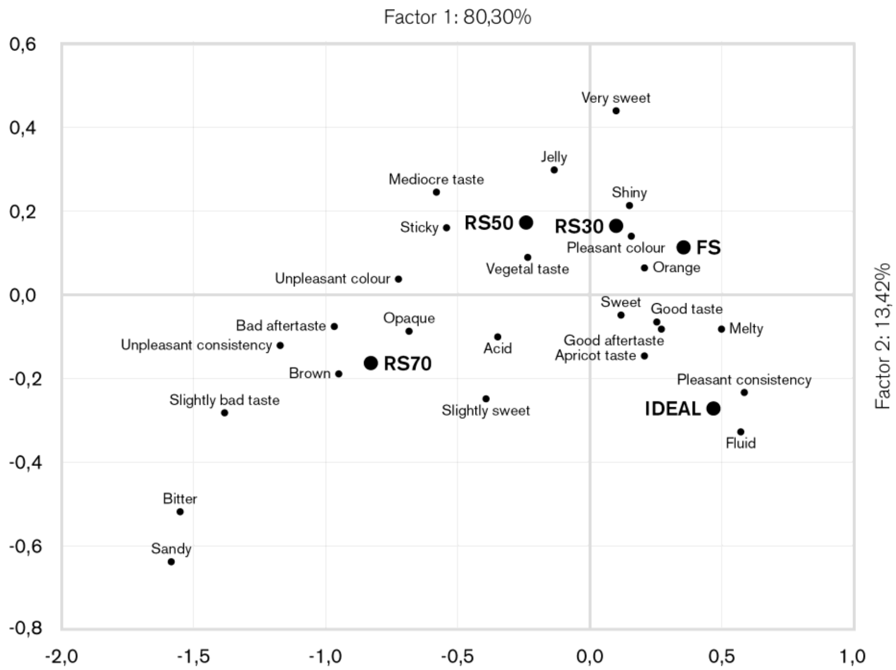


Figure 4. Correspondence analysis of the CATA test data of fruit filling formulated with different sucrose content. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.



A fibre syrup for the sugar reduction in fruit filling for bakery application

Alessandro Carcelli[13], Anna Albertini[1], Elena Vittadini[2], Eleonora Carini[1*]

[1] Department of Food and Drug, University of Parma, Parco Area delle Scienze 47/a, 43124 Parma, Italy

[2] School of Biosciences and Veterinary Medicine, University of Camerino, via Gentile III da Varano, 62032 Camerino, Macerata, Italy (current address)

[3]HI-FOOD S.p.A., Parco Area delle Scienze Pad. 27, 43124, Parma, Italy

[*] **Corresponding author**

E-mail address: eleonora.carini@unipr.it

address: Parco Area delle Scienze, 47/a, 43122 Parma, Italy

phone: +039 0521 906520

e-mail address of each author:

alessandro.carcelli1@studenti.unipr.it

anna.albertini@studenti.unipr.it

elenagiovanna.vittadini@unicam.it

eleonora.carini@unipr.it

Abstract

Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of *Cicer arietinum* seed) has been used to formulate reduced-sugar fruit fillings. Three reduced-sugar (by 30, 50 and 70%) recipes were developed starting from a standard formulation, in order to reach the “reduced in sugar” and “high in fibre” label claims. Physicochemical and sensory properties of the fruit fillings were assessed during 180 days of storage at two different temperatures (5°C and 25°C). Increased firmness, adhesiveness, consistency coefficient (K, flow behaviour), bake stability and colour differences have been observed in reformulated recipes with increasing fibre syrup content if compared to the control. Storage decreased bake stability and induced darkening of the product in all samples. 30% sugar-reduced filling were the most appreciated by consumers, and not distinguishable from the control. Overall results confirmed the syrup technological functionality when used to obtain a 30% sugar-reduction.

Keywords: Fruit filling, sugar reduction, fibre syrup, dietary fibre.

1. Introduction

In Europe, the estimated daily energy intake from sugar ranges between 15-21% in adult and between 16%-26% in children of the total energy intake (Azaïs-Braesco et al., 2017). These values are not in line with the World Health Organization (WHO) guidelines (World Health Organization, 2015) which recommends a sugar intake < 10% of the total energy intake; high levels are related to health problems as obesity, diabetes, and dental caries (Schwingshackl et al., 2017; Te Morenga et al., 2012; Touger-Decker & van Loveren, 2003). Awareness campaigns from health institutions and governments are informing consumers on the adverse effect of a high sugar diet. As a result, the request of reduced-sugar products on the market is increasing (FIE Global, 2020).

To fulfil a high-quality demand, food technologists are called to a complex challenge namely the replacement of the several quality and technological roles of sugar in food. Among the strategies proposed to reduce sugar in foods (Hutchings et al., 2019), the use of sugar substitutes is considered the most appropriate and viable in an industrial context (Hutchings et al., 2019). Sugar sweetness can be nowadays easily replaced using non-caloric sweeteners. On the contrary, the replacement of the sugar bulking effect with a proper ingredient remains difficult, especially for high sugar content products as jam, jelly, fruit filling in which sugar can be up to 60% of the product.

Technological functionalities of sugar substitutes should also satisfy the more and more increasingly consumer request for clean label ingredients (Asioli et al., 2017; Osborn, 2015). Ingredients able to simultaneously satisfy both the technological requirement and the clean label standard are of great interest. Dietary fibres are easily recognisable and positively accepted by the consumers (Dhingra et al., 2012), and they have been used either as bulking agents or as nutritional improvers (Buttriss, 2017; Shinwari & Rao, 2020).

In the frame of high sugar foods, bakery products which contain fruit-based filling are a growing sale sector (Cropotova et al., 2016). Fruit filling are mainly based on sugar, water, fruit puree/jam, flavour, and thickening agent (Wei et al., 2001). Despite the high sugar content of this food preparation, very few researchers worked on its sugar reduction; it has been reported the use of polydextrose (E1200) that allowed to obtain similar structures between reduced- and full- sugar products (Agudelo et al., 2015a; Agudelo et al., 2015b).

A commercial fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of *Cicer arietinum* seed) was previously characterized and tested as sugar replacer in cookies and ripple sauces with encouraging results (Carcelli, Alberti et al., 2021; Carcelli, Suo et al., 2021).

In this work, same commercial fibre syrup was tested as buking agent ingredient to develop reduced-sugar fruit filling formulations. Fruit fillings with different reduced-sugar levels were developed and characterised for their physicochemical and sensory properties at 5°C and 25°C for a storage period of 180 days to replicate the typical storage condition of the product in the industrial context.

2. Materials and methods

2.1 Materials

A fibre syrup (MELTEC®) was obtained from HI-FOOD S.p.A. (Parma, Italy). It is a clean label ingredient, which does not impart sweetness, with a consistency like honey, a gold brownish colour. Its dietary fibre content is ≈ 66% [(g fibre/100 g sample), High Molecular Weight Dietary Fiber and Low Molecular Weight Dietary Fiber (AOAC method 2009.01)], with a sugar content < 1.0% (g sugar/100 g sample), and a moisture content ≈ 25% (g water/100 g sample). The commercial fiber syrup was also characterized in terms of Brix degrees (portable refractometer HB 95, Lega Italy, Ravenna, Italy), water activity at 25°C (a_w, Aqualab 4 TE, Decagon Devices Inc., Pullman, WA, USA), pH (potentiometer pH7+DHS Food, XS Instruments, Modena, Italy) and colour. Colour analysis was performed using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan) equipped with a standard illuminant D65 and a 10°position of the standard observer. According to CIE Lab system, L* [0 (black) and 100 (white)], a* (–a*= greenness and + a*=redness) and b* (–b*= blueness and + b*= yellowness) parameters were measured. At least, three measurements were taken for each analysis.

Other ingredients used in the fruit filling recipes were: low-methoxyl (LM) pectin Classic AB 902 (Herbstreith&Fox KG, Werder, Germany), glucose syrup 60 dextrose equivalent DE "Glucoplus 361" (Uniglad Ingredienti, Cuneo, Italy), tricalcium citrate (Giusto Faravelli, Milano, Italy), potassium sorbate (Giusto Faravelli, Milano, Italy), crystalline sucrose (British sugar, Peterborough, UK), apricot jam (Rogelfrut, Cuneo, Italy), citric acid (Brenntag, Milano, Italy), apricot flavour NATLQ10989 (Internation Taste Solution, Newbury, UK).

2.2 Fruit filling preparation

Full-sugar (FS) and reduced-sugar (RS) fruit filling recipes, based on industrial recipe, are shown in Table 1. RSs were formulated replacing all the glucose syrup and increasing level of crystalline sucrose with fibre syrup in a 1:1 weight ratio. The replacement of sugar was designed in order to achieve its reduction by 30% (RS30), 50% (RS50) and 70% (RS70). All fruit filling samples were produced using a bowl chopper (Polyfunctional QB 8-3, Roboqbo, Bologna, Italy). As a first production step, LM pectin was mixed with crystalline sucrose in a 1:5 ratio, the mixture obtained was then dissolved in half of the water present in the recipe and pre-heated at 80°C with a blender (Minipimer MQ5035, Braun, Germany) at 13500 rpm for 5 min. In parallel, the other ingredients as crystalline sucrose, tricalcium citrate, glucose syrup or fibre syrup (for RS recipes), apricot jam and the remaining water in which the potassium sorbate was previously dissolved, were added together in the bowl chopper. The ingredients were subsequently mixed at 500 rpm and subjected to a heat treatment at 75°C until reaching 73 °Brix. Subsequently, the pre-mix of LM pectin and crystalline sucrose was added to the bowl chopper continuing the mixing process at 500 rpm at 90°C under vacuum (1 bar) to concentrate the preparation at 72 °Brix. Afterwards, the citric acid dissolved in few drops of water and the liquid apricot flavouring were added checking the pH until reaching a value of 3.6. As a final step, the product was cooled under vacuum (1 bar) at 800 rpm until reaching 65°C. The filling was transferred into plastic container to be analysed after cooling to RT (t0) or stored at 25°C or 5°C for analysis after 30, 60 and 180 days (t30, t60, t180). Filling formulations were characterized during storage both at 5°C and 25°C to verify their quality in different and frequent storage and consuming conditions as raw materials or components in final products.

Two batches of product for each formulation were produced in two different days.

2.3 Fruit filling characterisation

2.3.1 Nutritional profile

Macronutrient profile of FS and RSs was calculated using the European Institute of Oncology database (IEO-DBA, 2020). Energy (kJ and kcal) was obtained multiplying all macronutrients for their energy factors cited in the EU Regulation on labelling of food products (Regulation (EU) No 1169/2001).

2.3.2 °Brix and pH

°Brix of filling was measured using a refractometer HB 95 (Lega Italy, Ravenna, Italy) while pH with a potentiometer pH7+ DHS Food (XS Instruments, Modena, Italy). At least three measurements were taken at 25°C for each formulation for a total of six determinations.

2.3.3 Water activity and moisture content

Water activity was measured at 25 °C with an Aqualab 4 TE (Decagon Devices Inc. WA, USA). Moisture content (MC, g of water/100 g of sample) was measured by weight loss by drying in a forced-air oven (M120-TBR, MPM Instruments Srl, Milano, Italy) at 70 °C to constant weight.

At least three measurements were taken for each formulation for a total of six determinations at each storage time.

2.3.4 Textural and rheological properties

Texture properties were determined using TA.XT2 Texture Analyzer (Stable Micro Systems, Godalming, UK) equipped with a P/20 probe. A cylindrical container (58 X 70 mm) was completely filled with the product which it was subjected to a penetration test (50% strain at a rate of 0.8 mm/s). Firmness (peak force, N) and adhesiveness (negative area, N mm) were determined. Five measurements were taken for each batch for a total of ten determinations at each formulation and storage time.

A controlled stress rheometer (MCR 702 twin drive, Anton Paar, Graz, Austria) operating at 25°C with a 50 mm diameter plate-plate geometry and a gap of 1 mm was used to study the flow behaviour of fruit fillings. Before each analysis, the exposed surface of samples was protected with paraffin oil, besides the samples were allowed to rest for 3 minutes until axial force reached ~0 N. Flow curves were obtained increasing shear rates from 1 to 100 s^{-1}. Power law equation was used to fit the experimental data, according to:

$$\sigma = \mathrm{K}\gamma^{\mathrm{n}}$$

where σ is the shear stress (Pa), γ is the shear rate (s^{-1}), K is the consistency coefficient (Pa_*s^n) and n the non-Newtonian index (dimensionless).

Three measurements were performed for each batch for a total of six determinations for each formulation.

2.3.5 Colour

Colour was measured using the method reported by Carcelli and co-workers (Carcelli et al., 2020) using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan) equipped with a standard illuminant D65 and a 10° position of the standard observer. The results were expressed in accordance with the CIE Lab system; ΔE was calculated using FS as a reference (Carcelli et al., 2020). Ten determinations were performed for each batch for a total of twenty determinations for each formulation.

2.3.6 Syneresis and bake stability

Syneresis was measured as described by Cropotova and co-workers (Cropotova et al., 2009). Samples of 5 g (F_0) were transferred into a 50 ml falcon tube, sealed with plastic cap and centrifuged at 3000 rpm for 20 min (centrifuge 5910R, Eppendorf, Milan, Italy). The weight of the supernatant fraction (F_1) was measured and grade of syneresis was calculated as percentage (%) = $(F_1/F_0)*100$. Three replicates for each batch for a total of six determinations for each formulation were carried out.

Bake stability was evaluated following Young and colleagues with slight modifications (Young et al., 2003). Fruit filling samples of 10 g were placed into a circular mould (∅ 35 mm) on a 7x7 cm layer of short crust. On the circular sample obtained, 4 points have been marked on the external part to measure the pre- and post-baking (200° C, 10 min, 903.008.05, IKEA, Leida, Netherlands) diameter. Bake stability percentage (B.S.%) has been calculated according with:

$$B.S.\% = 100 - \left[\left(\frac{\varnothing pb - \varnothing bb}{\varnothing bb}\right) * 100\right]$$

where $\varnothing pb$ is diameter post baking while $\varnothing bb$ is diameter before baking.

Three measurements were performed for each batch changing the position of the short crust in the oven, for a total of six determinations for each formulation.

2.3.7 Sensory analysis

Sensory analysis of filling samples was realized using both an acceptability and a rapid profiling check-all-that-apply (CATA) test performed on samples immediately after production and after 60 and 180 days (t0, t60, t180). The tests were performed to 50 untrained judges using the method reported by Carcelli and co-workers (Carcelli et al., 2020). For CATA test the attributes random reported in the questionnaire were: pleasant colour, unpleasant colour, opaque, orange, brown, shiny, acid, bitter, sweet, very sweet, slightly sweet, good taste, bad taste, mediocre taste, vegetal taste, apricot taste, good aftertaste, bad aftertaste, pleasant consistency, unpleasant consistency, melty, jelly, sticky, fluid, sandy. Data were collected as the times each attribute was selected for each sample.

2.3 Statistical analysis

Data were processed with a three-way ANOVA using three fixed factors: recipe (R), storage time (St) and storage temperature (ST). The evaluation of single factor and their interactions in the variability of each parameter was obtained with the partition of total variance of sum square (SS%). Significant differences ($p \leq 0.05$) among different samples were assessed by one-way-analysis of variance (ANOVA) with a Duncan post-hoc test using an IBM SPSS statistical software (Version

24.0, SPSS Inc., Armonk, New York, USA). The contingency table of CATA dataset was obtained on the basis of samples and attributes. A correspondence analysis was performed to summarize the relationship between samples and attributes using Statistica software (Version.13.3, TIBCO Software Inc.).

3. Results and discussion

The high levels of sucrose and glucose syrup used by fruit fillings manufacturers strongly affect products overall quality. In this study, all the glucose syrup and increasing level of crystalline sucrose have been partially replaced with a commercial fibre syrup, in an attempt to develop products with reduced-sugar content. The physico-chemical characterization of the semi-solid fibre indicated that the fibre syrup had ~75 Brix, water activity ~0.88 and pH of ~6.4. As for fiber syrup colour, L* resulted ~23, a* ~0.34 and b* ~3.34. The values of the coordinates indicated the marked presence of redness and yellowness tones, thus confirming the brownish colour.

FS and RSs samples were prepared keeping constant pH and °Brix to replicate the industrial process. In particular, pH = 3.6 ± 0.1 and °Brix = 72 ± 1 were reached in all samples increasing the citric acid content and prolonging (where necessary) the cooking time, respectively. pH and °Brix were also monitored throughout the entire storage time (data not showed) indicating significant but slight changes and remaining in the desired range.

3.1 Nutritional label information

Pillar of the study was the development of a filling formulation with an improved nutritional profile in terms of lower sugar and higher dietary fibre contents, if compared with a standard filling formulation. The nutritional labels of FS and RSs are reported in Table 2.

Energy decreased remarkably with the increase of the fibre syrup moving from 964 KJ/230 Kcal of FS to 831 KJ/198 Kcal, 724 KJ/173 Kcal and 620 KJ/148 Kcal of RS30, RS50 and RS70, respectively.

The energy decrease was associated to the decrease of the carbohydrates in favour of the dietary fibres which have a lower energy conversion factor as indicated in the EU Regulation on labelling of food products (Regulation (EU) No 1169/2001). Moreover, RSs presented a sugar content reduced by 30% (RS30, from 55.8 g/100 g to 39 g/100 g), 50% (RS50, from 55.8 g/100 g to 27.5 g/100 g) and 70% (RS70, from 55.8 g/100 g to 17 g/100) if compared with FS. A slight increase of protein content was observed for RS50 and RS70 (respectively 0.6 g/100 g and 0.9 g/100 g) due to the increase of the fibre syrup in the formulation which intrinsically has a low amount of residual protein content. The increase of the fibre syrup led to an increase in the fibre content in the recipe from 1 g/100 g of FS to 15 g/100 g, 22.5 g/100 g and 30 g/100 g for RS30, RS50 and RS70, respectively. The decrease of sugar and the increase of fibre contents would allow to label all the RSs with the double nutritional claims “reduced in sugar” and “high in fibre” based on the EU regulation on nutritional and health claims (Regulation (EC) No 1924/2006).

3.2 Physico-chemical characterization

Product stability at rheological, chemical and microbiological level is strongly related to water activity (a_w) and moisture content (MC). Both parameters for all samples during storage are reported in Table 3 while the statistical outputs can be found in Table 4.

MC was affected by recipe (R) increasing with the decrease of sugar in the recipe (from ≈20% in FS to ≈23% in RS70 at t0). Similarly, a_w was highly affected by R showing an increase with the decrease of sugar moving from ≈0.80 in FS to ≈0.87 in RS70. Similar trends were noticed at all storage temperatures and times. These results were related to the water content (≈25% g water/100 g sample) of the fibre syrup used to partially replace sugar and/or to its different interaction with water than those developed by sugar. Indeed, sugar is highly hygroscopic and has higher capacity than fibre to bind water thanks to the higher amount of available free hydroxyl group compared to long chain polysaccharides. The increase of a_w and MC when sugar was replaced by vegetable fibres was previously reported in studies conducted on cakes, muffin and fruit jellies (Milner et al., 2020; Riedel et al., 2015; Zahn et al., 2013). However, the increase of both parameters does not affect product microbiological stability because the product is acidic (pH ~3.6) and it is stabilised with a hot filling process. The use of fiber syrup as sugar substitute in non-acidic products should envisage acid regulation to ensure microbiological safety. MC was affected also by St which slightly fluctuated during storage probably due to a macroscopic water redistribution in the product. The storage temperature did not affect neither the moisture content and the water activity with only a slightly significant difference for FS and RS30 at t60.

Fruit fillings rheological properties were assessed using both empirical and fundamental techniques in order to verify agreement between the two analytical approaches providing useful information to those food industries able to implement only cheaper and easier rheological methods. Fillings' firmness and adhesiveness parameters (Figure 1) aimed to give some information related to the mouthfeel of the product which is an important quality characteristic of semi-solid foods as filling. These food materials indeed shall not be chewed and their texture features are directly perceived in the mouth by tongue receptors (Agudelo et al., 2015a). Three-way ANOVA (Table 4) highlighted that firmness and adhesiveness were primarily affected by R with a significant increase of both parameters with the sugar decrease in the recipes. The increase of firmness and adhesiveness was likely affected by the increase of the fibre syrup which bulking effect strongly impacted on the overall structure. This phenomenon is probably due to the interactions among the polysaccharide long chains present in the syrup which probably affected the macrostructure. At t30, t60 and t180, FS, RS30 and RS50 had comparable firmness and adhesiveness while RS70 was harder and more adhesive than all other samples.

Flow properties play a fundamental role in the quality characteristics of filling. Its fluidity and structure may modulate the flavour perception in the mouth and therefore influence consumer acceptability; moreover, pumping and baking phase at industrial level may be strongly affected by a change in system fluidity (Agudelo et al., 2015a; Razak et al., 2018; Wei et al., 2001). Flow curves fitting allowed to calculate the non-Newtonian index (*n*, data not showed) and the consistency coefficient (K, Table 4, Figure 2).

n index of fillings fell between 0.33-0.40, characterising the product as pseudo plastic fluid (n<1), as previously reported in fruit filling (Nalawade et al., 2017; Wei et al., 2001). *n* index was more affected by St with only slight significative variation during storage (Table 4). K was instead strongly influenced by R showing a significantly increase with the reduction of sugar. Higher K at all storage times and temperatures was observed for RS70 if compared to other samples. A good positive relation (r^2 = 0.96) was found between firmness and K, probing accordance between empirical and fundamental rheological analysis. Overall, the fibre syrup used in this work increased firmness and K when used to reduce sugar above 30%. On the contrary, polydextrose (E1200) was found to marginally affect the rheological properties of fruit filling when used to completely replace sugar (Agudelo et al., 2015b).

Consumer acceptability is strongly influenced by the colour which is one of the most important appearance factors, influencing also the flavour perception and the overall purchase decision (Pathare et al., 2013). The colour properties of fillings were therefore analysed (Table 5).

Colour was most affected by St (Table 4): a significant decrease of all colour parameters was noticed at both storage temperatures in all samples (more pronounced in FS). A decrease of L^*, a^* and b^* during storage was observed also in previous studies on apricot (Touati et al., 2014) and strawberry jam (Wicklund et al., 2005). The darkening of jam products during storage has been associated to the fruit anthocyanidins degradation. Anthocyanidins originate from anthocyanins degradation which occurs during thermal and mechanical production steps. Anthocyanidins are less stable than anthocyanins to light and oxygen and consequently more prone to browning reactions (Wicklund et al., 2005). .

Colour was less affected by R (Table 4) where in fresh products a significative decrease of all parameters was noticed with the increase of the fibre syrup due to its intrinsic brownish colour. Colour changes as a function of St and R were also highlighted by the ΔE values (Table 5). However, it is important to remark that all the formulations studied did not contain any food colouring ingredients which could be included in the formulation in the industrial scale up in order to stabilise the product during storage and to counterbalance the presence of the fibre syrup.

Other fruit filling' quality features are the stability – preservation of the dimension at high temperature during baking (Agudelo et al., 2014; Young et al., 2003) and the absence of water syneresis as a migration of water from the fruit filling to the dough may lead to product inhomogeneity and stickiness (Cropotova et al., 2016). All filling formulations produced did not show water syneresis during storage. The absence of water syneresis also in the RSs in which MC and a_w were higher than in FS indicates that the fibre syrup had a positive technological role acting as stabilising ingredient.

Bake stability results (Table 6) indicated its addiction by St showing a decrease during storage in all samples. Moreover, only at t0, formulations containing the fibre syrup showed a significantly increase of their bake stability index if compared with FS highlighting an improvement of this quality indicator in the fresh product.

3.3 Sensory analysis

All the fruit fillings were considered acceptable by the consumers (overall acceptability scores higher than 5 in all cases) with FS and RS30 considered the most preferred (score ≈7) (Figure 3). The lowest scores were attributed to RS70, in particular for consistency which was evaluated with a score < 5 indicating a worsening of the fruit filling structure probably due to its higher firmness, adhesiveness and K compared to the other formulations. No significative differences for sensory attributes were registered during storage. These findings are encouraging considering that the product sensory stability for long lasting shelf-life is a relevant quality feature. A better elucidation of the fillings' consumers perception was assessed using a CATA test. The two dimensions of the factor plane representing the CATA test conducted at t0 (Figure 4) explained ≈93% of the variance, with dimension 1 explaining ≈80% and dimension 2 explaining ≈13%. IDEAL fruit filling was described as fluid, pleasant consistency, melty, sweet, apricot taste, good aftertaste, good taste. Attributes as "melty", "sweet" and "fruity" were also found in the IDEAL filling in the study of (Agudelo et al., 2015b). FS and RS30 were described by similar attributes: pleasant colour, orange, shiny, very sweet. On the opposite, RS50 and RS70 were characterised by negative attributes as jelly, vegetal taste, mediocre taste, sticky and unpleasant colour (RS50), and opaque, acid, slightly sweet, bad aftertaste, unpleasant consistency, brown, bad taste, sandy and bitter (RS70). The negative attributes related to consistency for RS50 and RS70 highlighted that the use of the syrup in high amount led to a detrimental effect on product texture increasing the "jelly" perception which is the opposite of the fluid attribute applied for the IDEAL product. Consumers' appreciation for the fruit filling fluid consistency was previously reported (Agudelo et al., 2015b). Overall, RS30 was the most appreciated reduced-sugar formulation based on both acceptability and CATA test, particularly for its texture properties. No remarkably differences on samples attributes were noticed during storage confirming the results of the acceptability test.

4. Conclusions

"Sugar reduced" and "high in fibre" claims could be used to label reformulated fruit fillings by means of the use of a syrup based on chickpea and maize fibre as sugar replacer. The use of the syrup increased the a_w, MC as well as firmness, adhesiveness, K consistency coefficient and bake stability, while decreased the colour coordinates $L*$, $a*$, $b*$. Storage time mainly affected the colour and the bake stability of all fruit fillings while the storage temperature presented a little or negligible effect on all studied parameters. When sugar was reduced by 30% the overall physicochemical and sensory properties of the reformulated fruit filling were found to be similar to the full-sugar counterpart.

The use of the fibre syrup as clean label ingredient was found to be a valuable ingredient on a technological standpoint, allowing to improve the nutritional profile of the product and to partially replace the bulking agent role of sugar.

Acknowledgments

The Authors would like to thank Francesca Petrelli for carrying out part of the experimental work.

Conflict of interests

AC was involved in the research as Industrial PhD student. Universities involved in this research have not received any funding.

Ethical guidelines statement

All judges were previously informed about the scope of the research and of its non-commercial purpose, as well as their anonymous and voluntary participation. Moreover, judges were informed of the composition of the fruit fillings to exclude any allergic subject. Judges were also informed about the possible use of the data raised by the study for any scientific or informative communication.

References

1. Agudelo, Alejandra, Varela, P., & Fiszman, S., 2015. Fruit fillings development: A multiparametric approach. LWT – Food Sci. Technol., 61(2),564-572.
2. Agudelo, A., Varela, P., & Fiszman, S., 2015. Methods for a deeper understanding of the sensory perception of fruit fillings. Food Hydrocolloids 46 (160-171).
3. Agudelo, Alejandra, Varela, P., Sanz, T., & Fiszman, S., 2014. Formulating fruit fillings. Freezing and baking stability of a tapioca starch-pectin mixture model. Food Hydrocolloids, 40, 203-213.
4. Asioli, D., Aschemann-Witzel, J., Caputo, V., Vecchio, R., Annunziata, A., Næs, T., & Varela, P., 2017. Making sense of the "clean label" trends: A review of consumer food choice behavior and discussion of industry implications. Food Res. Int., 99, 58-71.

5. Azaïs-Braesco, V., Sluik, D., Maillot, M., Kok, F., & Moreno, L. A., 2017. A review of total & added sugar intakes and dietary sources in Europe. Nutr. J., 16(1), 1-15.
6. Buttriss, J. L., (2017). Challenges and opportunities in the use of low-energy sugar replacers. Nutr. Bulletin, 42(2), 108-112.
7. Carcelli, A., Albertini, A., Vittadini, E., & Carini, E., 2021. Strawberry ripple sauce: A semi-solid fibre syrup to reduce sugar content. Int. J. Gastron. Food Sci, 100411.
8. Carcelli, A., Crisafulli, G., Carini, E., & Vittadini, E., 2020. Can a physically modified corn flour be used as fat replacer in a mayonnaise?. Eur. Food Res. Technol., 246(12), 2493-2503.
9. Carcelli, A., Suo, X., Boukid, F., Carini, E., & Vittadini, E., 2021. Semi- solid fibre syrup for sugar reduction in cookies. Int. J. Food Sci. Tech., 56(10), 5080-5088.
10. Cropotova, J., Tylewicz, U., Dellarosa, N., Laghi, L., Romani, S., & Dalla Rosa, M., 2016. Effect of freezing on microstructure and degree of syneresis in differently formulated fruit fillings. Food Chem., 195,71-78.
11. Dhingra, D., Michael, M., Rajput, H., & Patil, R. T., 2012. Dietary fibre in foods: A review. J. Food Sci. Tech. 49(3), 255-266.
12. FIE Global, 2020. Delivering taste and texture in food and beverage, Available:https://www.figlobal.com/content/dam/Informa/figlobal/fieurope/en/2020/documents/HLN20FIE-GM-Delivering-taste-and-texture-in-food-and-beverages.pdf (accessed 19 December 2020).
13. Hutchings, S. C., Low, J. Y. Q., & Keast, R. S. J., 2019. Sugar reduction without compromising sensory perception. An impossible dream? Crit. Rev. Food Sci., 59(14), 2287-2307.
14. European Institute of Oncology, 2015. Food composition database for epidemiological studies in Italy [Online]. Available: http://www.bda-ieo.it [24 July 2020].

15. European Union, 2006. Regulation No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. Official Journal of the European Union, L404, 9-25.
16. European Union, 2011. Regulation No N 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. Official Journal of the European Union, L304, 18-63
17. McCleary, B. V., De Vries, J. W., Rader, J. I., Cohen, G., Prosky, L., Mugford, D. C., ... & Okuma, K., 2010. Determination of total dietary fiber (CODEX definition) by enzymatic-gravimetric method and liquid chromatography: Collaborative study. Journal of AOAC international, 93(1), 221-233. doi.org/10.1093/jaoac/93.1.221
18. Milner, L., Kerry, J. P., O'Sullivan, M. G., & Gallagher, E., 2020. Physical, textural and sensory characteristics of reduced sucrose cakes, incorporated with clean-label sugar replacing alternative ingredients. Innov. Food Sci. Emerg. 59, 102235.
19. Nalawade, T., Chavan, R. S., & Joshi, A., 2017. Rheological Characterization of Fruit Fillings, in: Meghwal, M., Goyal M.R., Chavan, R.S., (Eds.), Dairy Engineering: Advanced Technologies and Their Applications, Apple Academic Press, pp. 37-52.
20. Osborn, S., 2015. Labelling relating to natural ingredients and additives. In Advances in Food and Beverage Labelling: Information and Regulations (pp.207-221).
21. Pathare, P. B., Opara, U. L., & Al-Said, F. A. J., 2013. Colour Measurement and Analysis in Fresh and Processed Foods: A Review. Food Bioprocess Tech., 6(1), 36-60.
22. Razak, R. A., Karim, R., Sulaiman, R., & Hussain, N., 2018. Effects of different types and concentration of hydrocolloids on mango filling. Int. Food Res. J. 25(3),1109-1119.
23. Riedel, R., Böhme, B., & Rohm, H., 2015. Development of formulations for reduced-sugar and sugar-free agar-based fruit jellies. Int. J. Food Sci. Tech., 50(6), 1338-1344.
24. Schwingshackl, L., Hoffmann, G., Lampousi, A. M., Knüppel, S., Iqbal, K., Schwedhelm, C., Bechthold, A., Schlesinger, S., & Boeing, H., 2017. Food groups and risk of type 2 diabetes

mellitus: a systematic review and meta-analysis of prospective studies. Eur. J. Epidemiol., 32(5), 363-375.

25. Shinwari, K. J., & Rao, P. S. (2020). Rheological and physico- chemical properties of a reduced- sugar sapodilla (Manilkara zapota L.) jam processed under high- hydrostatic pressure. J. of Food Process Eng., *43*(6), e13388.
26. Te Morenga, L., Mallard, S., & Mann, J., 2012. Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. BMJ 7492 1-25.
27. Touati, N., Tarazona-Díaz, M. P., Aguayo, E., & Louaileche, H., 2014. Effect of storage time and temperature on the physicochemical and sensory characteristics of commercial apricot jam. Food Chem., 145, 23-27.
28. Touger-Decker, R., & van Loveren, C., 2003. Sugars and dental caries. The American J. of Clinical Nutr. 78(4), 881S-892S.
29. Wei, Y. P., Wang, C. S., & Wu, J. S. B., 2001. Flow properties of fruit fillings. Food Res. Int., 34(5), 377-381.
30. Wicklund, T., Rosenfeld, H. J., Martinsen, B. K., Sundfør, M. W., Lea, P., Bruun, T., Blomhoff, R., & Haffner, K., 2005. Antioxidant capacity and colour of strawberry jam as influenced by cultivar and storage conditions. LWT – Food Sci. Technol., 38(4), 387-391. doi.org/10.1016/j.lwt.2004.06.017.
31. World Health Organization, 2015. Guideline: sugars intake for adults and children. Geneva: World Health Organization.
32. Young, N. W. G., Kappel, G., & Bladt, T., 2003. A polyuronan blend giving novel synergistic effects and bake-stable functionality to high soluble solids fruit fillings. Food Hydrocolloids 17(4), 407-418.
33. Zahn, S., Forker, A., Krügel, L., & Rohm, H., 2013. Combined use of rebaudioside A and fibres for partial sucrose replacement in muffins. LWT – Food Sci. Technol., 50(2), 695-701.

Table 1. Fruit filling recipes (% wt).

	FS	RS30	RS50	RS70
Sucrose	32	30.6	19.3	8.3
Glucose syrup	20	-	-	-
MELTEC®	-	21.4	32.7	43.7
Water	26.9	26.8	26.75	26.72
Apricot jam	20	20	20	20
Pectin	0.8	0.8	0.8	0.8
Citric acid	0.14	0.24	0.29	0.32
Tricalcium citrate	0.08	0.08	0.08	0.08
Potassium sorbate	0.05	0.05	0.05	0.05
Apricot flavour	0.03	0.03	0.03	0.03

FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 2. Nutritional composition based on Reg EU 1169/2011 of fruit fillings at different sucrose content (g/100g).

	FS	RS30	RS50	RS70
Energy (kJ)	964	831	724	620
Energy (kcal)	230	198	173	148
Fat	0	0	0	0
-of which saturated	0	0	0	0
Carbohydrates	57.0	41	30.5	20
-of which sugars	55.8	39	27.5	17
Fibre	1.0	15.0	22.5	30.0
Protein	0	0	0.6	0.9
Salt	0	0	0	0

FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 3. Moisture content (MC), water activity (a_w) of fruit filling at different sugar content during storage (t0, t30, t60, t180) at different temperatures (5°C, 25°C).

		t0	t30	t60	t180
Moisture content (MC) g H_2O/ 100 g of sample					
5 °C	FS	20.50 ±0.02 bB	22.50 ±0.01 bA	23.50 ±0.01 bA*	22.83 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.83 ±0.01 abA	24.17 ±0.01abA*	23.83 ±0.01 abA
	RS50	22.50±0.01 aB	24.50±0.02 aA	25.00±0.02 aA	24.67±0.02 aA
	RS70	23.00±0.01aB	23.67±0.01 abB	25.00±0.01 aA	23.67±0.01 abB
25° C	FS	20.50 ±0.02 bB	22.00 ±0.01 bA	22.83 ±0.01 bA*	22.33 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.33 ±0.01 aAB	23.67 ±0.01 bA*	23.83 ±0.01 aA
	RS50	22.50±0.01 aB	24.33 ±0.01 aA	24.67 ±0.01 aA	24.00 ±0.01 aA
	RS70	23.00±0.01aB	23.67±0.01 aB	24.67±0.01 aA	23.83±0.01 aAB
Water activity (a_w)					
		t0	t30	t60	t 180
5 °C	FS	0.800 ±0.010 dA	0.801 ±0.014 dA	0.805 ±0.007 dA	0.794 ±0.004 dA
	RS30	0.836 ±0.007 cAB	0.836 ±0.009 cAB	0.842 ±0.004 cA	0.832 ±0.003 cB
	RS50	0.861 ±0.005 bA	0.858 ±0.005 bA	0.864 ±0.005 bA	0.857 ±0.008 bA
	RS70	0.874 ±0.003 aA	0.874 ±0.002 aA	0.876 ±0.003 aA	0.866 ±0.003 aB
25° C	FS	0.800 ±0.010 dA	0.798 ±0.009 dA	0.804 ±0.010 dA	0.784 ±0.004 dB
	RS30	0.836 ±0.007 cA	0.833 ±0.009 cA	0.839 ±0.003 cA	0.824 ±0.006 cB
	RS50	0.861 ±0.005 bA	0.857 ±0.004 bA	0.858 ±0.010 bA	0.846 ±0.010 bB
	RS70	0.874 ±0.003 aA	0.871 ±0.004 aA	0.875 ±0.003 aA	0.865 ±0.002 aB

All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample ($p \leq 0.05$), where the small letters due to the sugar content, capital letter due to the time of storage and * due to temperature of storage. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 4. Partition of the total variance of sum square (SS%) of each single factor (R: recipe, St: storage time; ST: storage temperature) and their interactions for each parameter studied. In brackets the significance ($p < 0.05$) of the influence of individual factors and their interactions.

	R	St	ST	R*St	R*ST	St*ST	R*St*ST
a_w	96.6 (0.00)	2.5 (0.00)	0.3 (0.00)	0.1 (0.90)	0.1 (0.71)	0.2 (0.04)	0.2 (0.89)
MC	45.6 (0.00)	45.7 (0.00)	1.3 (0.07)	5.8 (0.12)	0.4 (0.81)	0.6 (0.71)	0.6 (0.99)
Firmness	48.5 (0.00)	39.4 (0.00)	2.4 (0.00)	5.0 (0.00)	0.3 (0.63)	4.0 (0.00)	0.4 (0.98)
Adhesiveness	63.4 (0.00)	21.5 (0.00)	5.0 (0.00)	4.7 (0.00)	0.3 (0.51)	4.8 (0.00)	0.3 (0.98)
n	17.8 (0.00)	37.8 (0.00)	11.1 (0.00)	15.5 (0.82)	0.0 (0.00)	15.6 (0.00)	2.2 (0.82)
K	78.7 (0.00)	9.7 (0.00)	4.9 (0.00)	1.0 (0.83)	0.3 (0.65)	4.5 (0.00)	0.9 (0.89)
L*	25.9 (0.00)	64.6 (0.00)	1.6 (0.00)	5.7 (0.00)	0.2 (0.63)	1.7 (0.00)	0.3 (0.40)
a*	29.5 (0.00)	57.5 (0.00)	0.2 (0.05)	2.5 (0.00)	0.4 (0.01)	8.8 (0.00)	1.1 (0.00)
b*	30.7 (0.00)	55.6 (0.00)	4.4 (0.00)	5.3 (0.00)	0.4 (0.00)	3.3 (0.00)	0.3 (0.00)
Bake stability	2.9 (0.00)	85.0 (0.00)	2.2 (0.00)	5.1 (0.00)	1.6 (0.00)	1.1 (0.00)	2.1 (0.00)

Table 5. Color parameters of fruit fillings at different sugar content during storage (t0, t30, t60, t180) at different temperatures (5°C, 25°C).

		t0		t30				t60				t180			
				5°C		25°C		5°C		25°C		5°C		25°C	
			ΔE		*ΔE*		*ΔE*		*ΔE*		*ΔE*		*ΔE*		*ΔE*
FS															
	*L**	35.42 ± 1.70 aA		33.16 ± 1.27aB		33.71 ± 1.89aB		30.71 ± 1.35aC		30.58 ± 1.39aC		30.51 ± 1.16aC		28.48 ± 1.01abD	
	*a**	10.71 ± 1.28aA	-	8.44 ± 1.28aB	-	9.19 ± 1.91aB	-	6.53 ± 1.24aC	-	5.70 ± 1.53aC	-	6.36 ± 1.14aC*	-	4.87 ± 0.92aC*	-
	*b**	15.00 ± 2.40aA		11.80 ± 1.83aB		13.35 ± 2.72aB		8.50 ± 1.39aC		8.03 ± 1.85aC		8.27 ± 1.56aC		5.42 ± 0.99aD	
	ΔE	-		4.5		2.8		9.1		9.8		9.4		13.2	
RS30															
	*L**	32.40 ± 1.50bA		30.98 ± 0.42bB		30.86 ± 0.75bB		29.57 ± 0.78bC		29.43 ± 1.10bC		29.52 ± 1.24bC		27.89 ± 1.05abD	
	*a**	9.18 ± 1.78bA	5.3	7.66 ± 0.80bB	3.9	8.51 ± 1.59bA	5.2	5.25 ± 1.32bC	2.18	5.16 ± 1.94abB	2.4	6.88 ± 1.25aD*	1.25	4.10 ± 1.05aB*	1.6
	*b**	10.85 ± 2.02bA		8.71 ± 0.76bB		9.03 ± 1.34bB		7.16 ± 0.95bC		6.03 ± 1.50bC		7.70 ± 1.47aC		4.10 ± 0.79bD	
	ΔE	-		3.0		2.5		6.1		6.9		4.8		9.6	
RS50															
	*L**	31.76 ± 1.01bA		29.70 ± 0.54cB		29.71 ± 0.52cB		28.97 ± 0.4cC*		28.28 ± 0.37cC*		28.28 ± 0.85cD		27.74 ± 1.14bC	
	*a**	8.56 ± 1.36bA	6.8	6.07 ± 0.90cB*	6.3	6.76 ± 0.71cB*	7.8	4.10 ± 0.62cC	4.0	4.35 ± 1.15bcC	3.8	4.78 ± 0.95bC*	3.77	4.15 ± 1.59aC*	1.7
	*b**	9.65 ± 1.26bA		7.12 ± 0.91cB		7.10 ± 0.58cB		5.82 ± 0.64cC*		5.34 ± 0.48cC*		5.66 ± 1.04bC		4.11 ± 1.01bD	
	ΔE	-		4.1		3.7		6.5		7.0		6.5		8.1	
RS70															
	*L**	30.75 ± 1.12cA		30.26 ± 1.0cA*		29.53 ± 0.4cB*		28.52 ± 0.3cB*		28.17 ± 0.40cC*		28.42 ± 0.92cB		28.90 ± 2.2aBC	
	*a**	6.91 ± 1.00cA	9.2	5.51 ± 0.90cB	6.1	5.92 ± 0.57cB	8.5	3.74 ± 1.12cC	4.7	3.45 ± 0.39cC	4.8	4.13 ± 0.75bC*	4.38	2.50 ± 0.88bD*	3.4
	*b**	8.00 ± 0.69cA		7.25 ± 1.26cB		6.68 ± 0.53cB		5.42 ± 0.73cC*		4.60 ± 0.41cC		5.13 ± 0.78bC		3.06 ± 0.81cD	
	ΔE	-		1.7		2.0		4.7		5.5		4.6		6.9	

All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among samples ($p \leq 0.05$), where the small letters due to the sugar content, capital letter due to the time of storage and * due to temperature of storage. Vertically are reported ΔE associated to the reformulation while horizontally ΔE associated to the storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Table 6. Bake stability of fruit filling at different sugar content during storage (t0, t30, t60, t180) at different temperature (5°C, 25°C).

		Bake stability (%)			
		t0	t30	t60	t180
5 °C	FS	77.75 ± 0.10 bA	69.75 ± 0.12 aB	69.13 ± 0.05 aB	62.38 ± 0.09 aC
	RS30	81.58 ± 0.05 aA	75.54 ± 0.13 aB	68.63 ± 0.07 aC	60.71 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	74.04 ± 0.10 aB	71.29 ± 0.10 aB*	58.46 ± 0.08 aC
	RS70	85.04 ± 0.05 aA	76.04 ± 0.10 aB	69.67 ± 0.09 aC	60.21 ± 0.07 aD
25° C	FS	77.75 ± 0.10 bA	74.67 ± 0.11 aA	69.08 ± 0.08 aB	65.33 ± 0.10 aB
	RS30	81.58 ± 0.05 abA	76.71 ± 0.07 aB	69.13 ± 0.08 aC	63.46 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	76.25 ± 0.04 aB	65.29 ± 0.05 aB	56.54 ± 0.08 aB
	RS70	85.04 ± 0.05 aA	72.04 ± 0.08 aB	65.17 ± 0.08 aC	62.13 ± 0.09 aC

All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample ($p \leq 0.05$), where the small letters due to the sugar content, capital letter due to storage time and * due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Figure 1. Firmness and adhesiveness of fruit fillings at variable sucrose content during storage at different temperatures (black: 5°C, grey: 25°C). Different letters close to the bar indicated significative difference among sample ($p \leq 0.05$) where the small letters were due to the sugar content while capital letter to storage time, and * symbol represented the difference due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

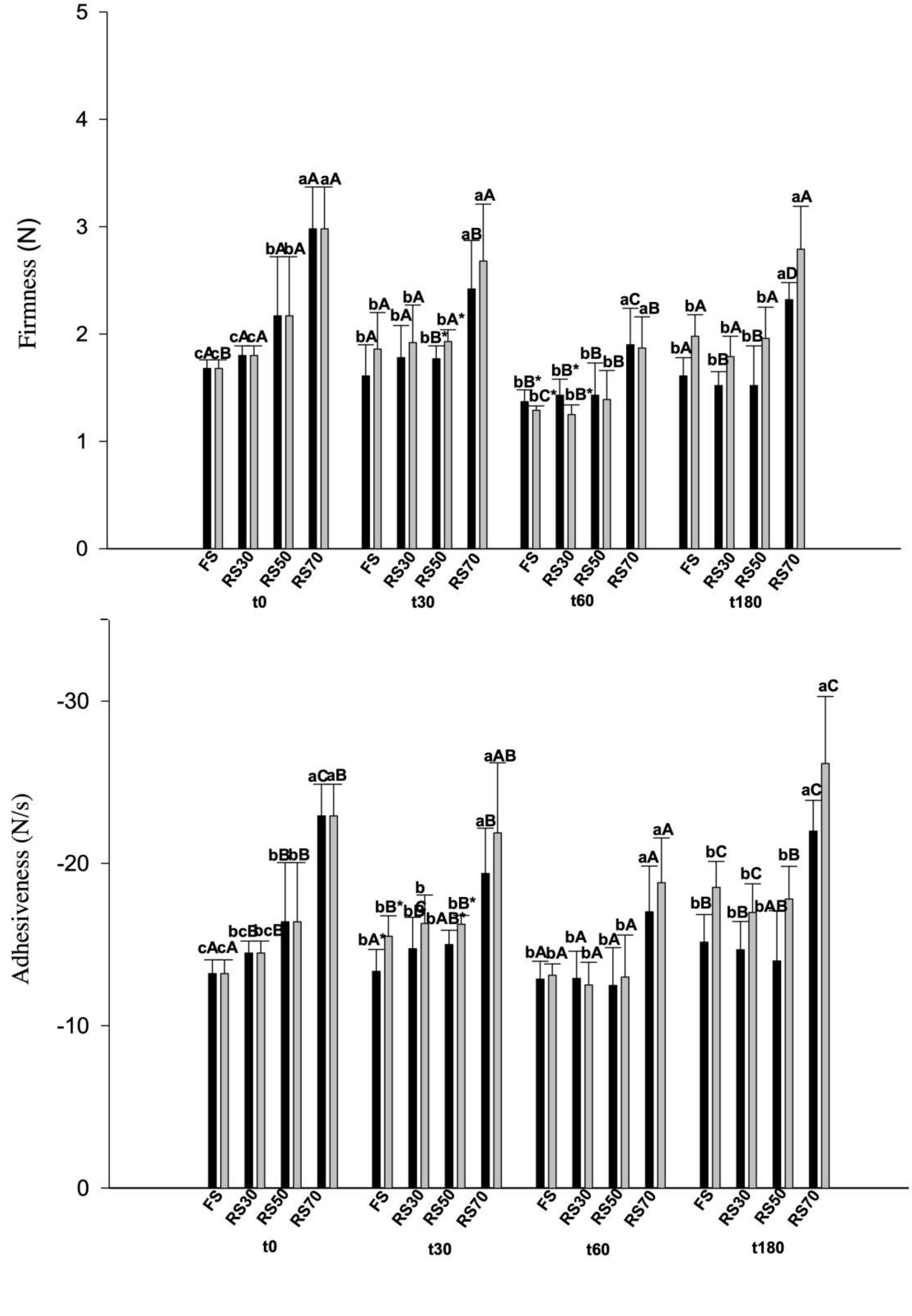


Figure 2. Consistency index of fruit fillings at variable sucrose content during storage at different temperatures (black: 5°C, grey: 25°C). Different letters close to the bar indicate significative difference among sample ($P \leq 0.05$) where the small letters due to the sugar content, capital letter due to storage time and * symbol due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

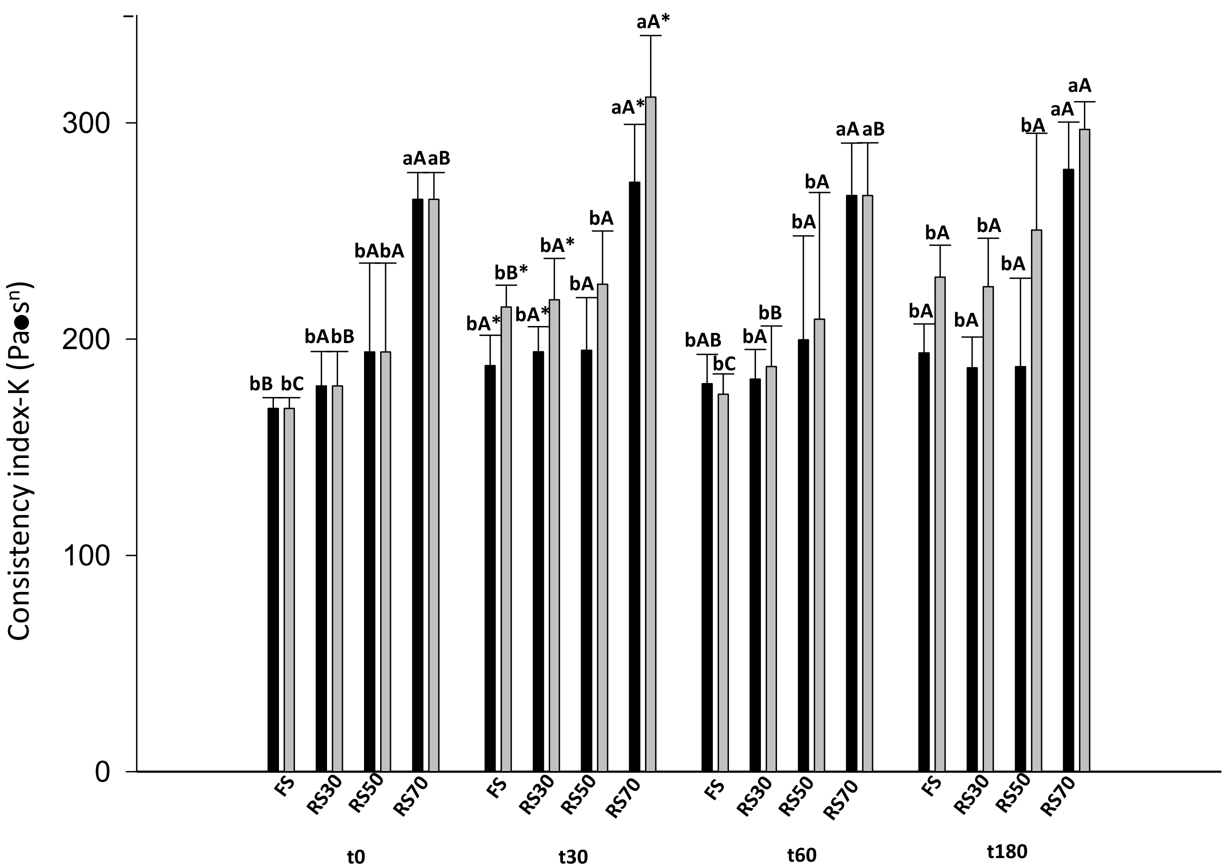


Figure 3. Sensory scores for consistency, taste, colour and overall acceptability of fruit filling at variable sucrose content. Different letters close to the bar indicate significative difference among sample ($p \leq 0.05$) where the small letters due to the sugar content, capital letter due to storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

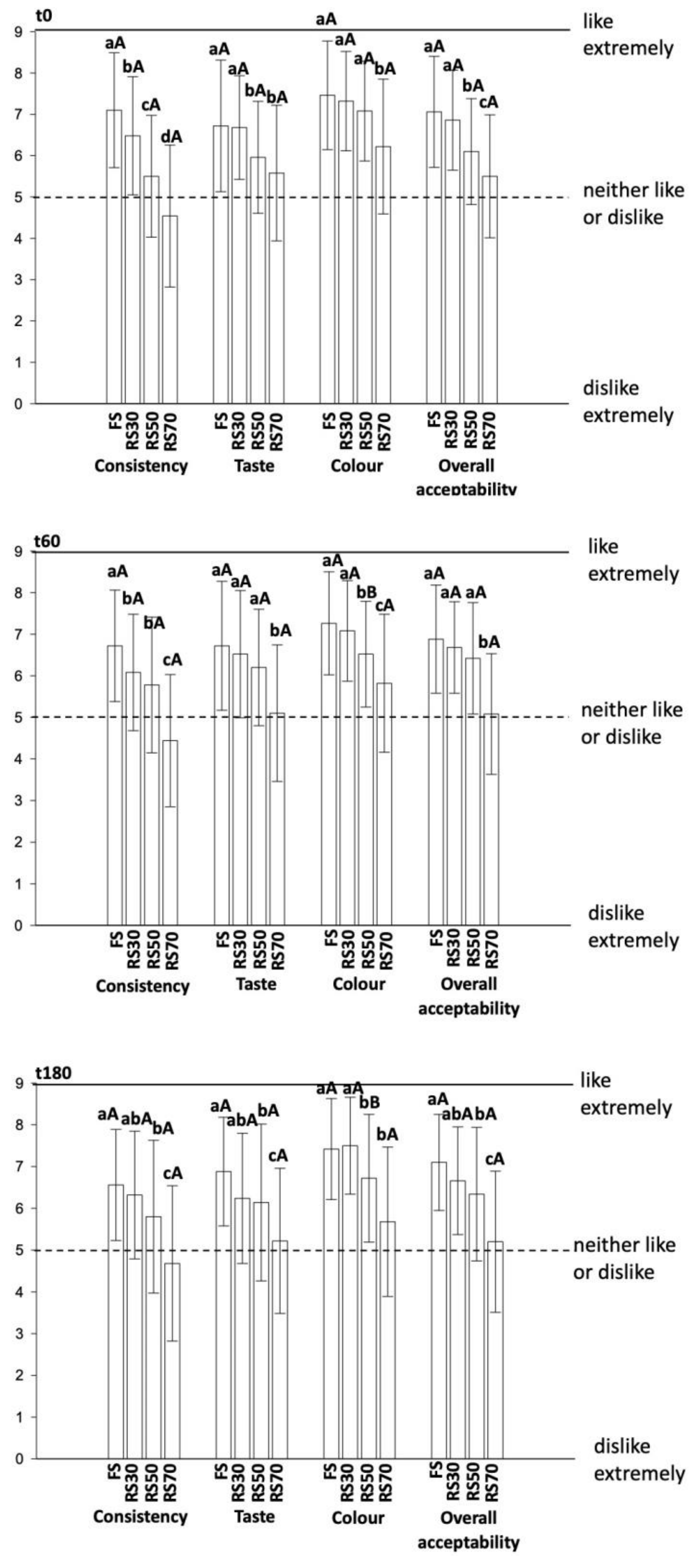
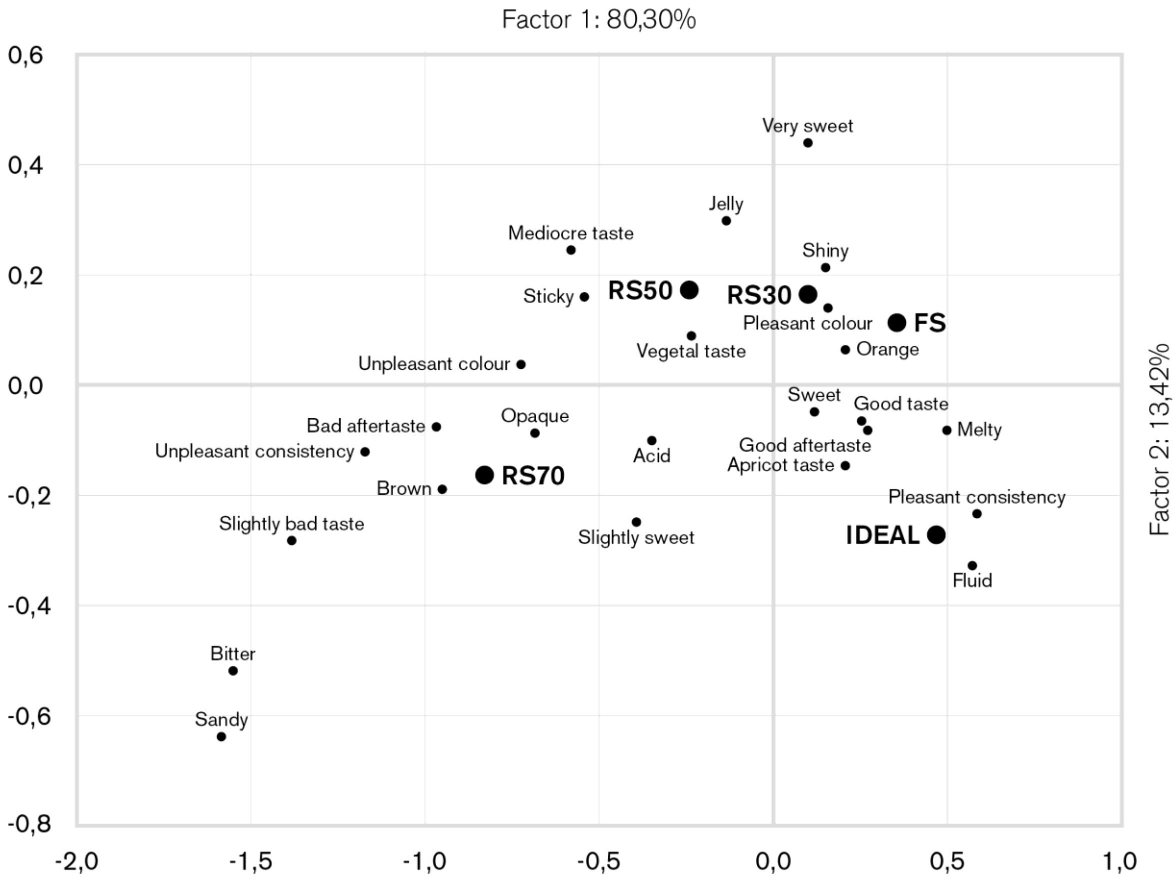


Figure 4. Correspondence analysis of the CATA test data of fruit filling formulated with different sucrose content. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.



Implications for gastronomy

Nowadays, one of the major trends in food science and gastronomy in the food reformulating area is the improvement of the nutritional value by the reduction of sugar. Due to the crucial role of sugar in food quality, its reduction is challenging. This problem is amplified by another trend that is the consumer demand for clean ingredients and labels which ask for not E numbers - sugar substitutes. The fibre syrup studied in this work can be used in different gastronomy applications such as fruit filling, jam, jellies and similar to replace the bulking agent functionality of sugar particularly where there is a clean label need and/or when “Sugar reduced” and “high in fibre” claims are pursued. In addition, the facility of using the fibre syrup as substitute (partially) of glucose syrup, sucrose and glucose makes interest and easy its use in pastry shops or in catering facilities to produce reduced in sugar and high in fiber fruit filling which can be used in products as croissant, doughnuts, cakes.”

This work was part of a wider project within an Industrial PhD project. The author Alessandro Carcelli was involved in the research as Industrial PhD student. Universities involved in this research have not received any funding to carry out the work.

Alessandro Carcelli: Methodology, Conceptualization, Formal Analysis, Investigation, Visualization, Writing – Original Draft

Anna Albertini: Methodology, Conceptualization, Investigation, Formal Analysis, Visualization

Elena Vittadini: Methodology, Writing – Review and Editing

Eleonora Carini: Methodology, Conceptualization, Investigation, Resources, Writing – Review and Editing, Supervision, Project Administration