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Fruit jellies enriched with dietary fibre: Development and characterization of a novel functional food product

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ABSTRACT

A novel functional food product, fruit jelly enriched with dietary fibre, was developed and characterized in this work. With that aim, 3 g of fibre of different varieties (apple A, bamboo B, psyllium P and wheat W) were added per 100 g of final product, so that it could be declared source of fibre. Fibre addition had a significant effect on the viscoelastic and mechanical properties, colour and syneresis (water loss) of the jellies, although these properties did not change after 30 days of cold storage, meaning that the product was stable. Fibre addition had a reinforcing effect on the gel strenght in the order: A > P > B > W. Psyllium enriched jelly was the only sample that did not show any syneresis, but it showed an undesirable high gumminess. Also, samples B and W left a "floury" mouthfeel. These undesired organoleptic properties were significantly reduced by combining psyllium with each one of the other fibre varieties in 1:1 proportion. Also, the presence of psyllium in these combinations eliminated syneresis of the samples. Therefore, the developed product showed acceptable attributes such as gel strength, texture, stability, appearance and flavour.

1. Introduction

Cooking jams, jellies and marmalades using fruits, sugar, pectin and edible acids is one of the oldest foods preserving processes known to mankind allowing fruit consumption in the off-season. In this case, food stabilization is achieved – besides the thermal treatment – by increasing the solids content (reducing water activity) and the acidity (reducing the pH) (Anonymous, 2018; Baker, Berry, & Hui, 1996). These parameters are of paramount importance for the texture, structure and overall quality of fruit jams, since proper gelation of high methoxyl (HM) pectin is only achieved in narrow ranges of pH (2.5–3.8), and sugar content (65–69 g/100 g) (Featherstone, 2016). Jam's minimum soluble solids content and maximum amount of added gelling agent (for example pectin) depends on the legislation of each country, being 65 g/100 g and 0.5 g/100 g, respectively, for the Argentine Food Code.

Dietary fibre consists of carbohydrate polymers with ten or more monomeric units, which are not hydrolysed by endogenous enzymes in the human small intestine and has physiological effects beneficial to health (Codex). Dietary fibre intake provides many health benefits, reducing the risk of developing coronary heart disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal disorders (Anderson et al., 2009; Li & Komarek, 2017). At present, fibre application research mainly includes addition of dietary fibre to flour, meat, and dairy products, or its use as additives (Yang, Ma, Wang, & Zheng, 2017). This has challenged the food industry to incorporate fibre in traditional products, or to develop new fibre-rich products (Rosell, Santos, & Collar, 2009).

In this context, it results highly interesting to develop and study fibre-rich fruit jams, because they are products of massive consumption, and likely suitable for fibre addition. Fibre enriched jellies are not intended to provide all the recommended dietary fibre intake (~30 g/day), but to contribute to this goal. According to the Argentine Food Code, a food product must contain at least 3 g/100 g of dietary fibre to exhibit the label "source of fibre". In general fruit marmalades available on the market contain fibre coming from the natural contribution of the fruit, but its concentration is unknown and usually lower than 3 g/100 g (Figueroa & Genovese, 2018). For this reason, the main objective of this work was to incorporate dietary fibre into a fruit jelly in order to develop healthy confectionary jams with the claim "source of fibre". Different varieties of fibre (from fruit and non-fruit sources, alone or in combinations) were employed, and their effects on the colour, syneresis, rheological and mechanical properties of the product were studied.

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2. Materials and methods

2.1. Materials

Apples (cv. Granny Smith), high methoxyl pectin (CP Kelko), food-grade sucrose (Ledesma), anhydrous glucose (Anedra), anhydrous citric acid (Parafarm), distilled water, and dietary fibres were used for sample preparation. Apple fibre (Vitacel AF 400–30), wheat fibre (Vitacel WF 101), and bamboo fibre (Qualicel, CFF) were from JRS (Rosenberg, Germany). Psyllium fibre was from Konsyl Pharmaceuticals Inc. (Easton, MD, USA), and consisted of a mix of Plántago Ovata seed husks (72 g/100 g), maltodextrin (27 g/100 g) and amorphous silica (1 g/100 g). Samples with apple, wheat, bamboo and psyllium fibre were identified as A, W, B and P, respectively.

pH and concentration of soluble solids (°Brix) of apple juice and jelly were measured with a digital pH-meter Altronix TPX II (Saen Srl, Buenos Aires, Argentina) and an Abbe refractometer WYA (ARCANO, Gea Srl, Santa Fe, Argentina), respectively.

The required amounts of ingredients per 100 g of jelly were: 45 g of apple juice (above the minimum required by the Argentine Food Code), 0.5 g of pectin, 41 g of sucrose, 16.4 g of glucose and 3.6 g of water. The proportions of juice/sucrose/glucose were based on the jelly recipe proposed by the pectin manufacturer Herbstreith & Fox (Anonymous, 2018). For fibre enriched jellies, 3 g of fibre per 100 g of final product was incorporated (in replacement of water), using the following combinations: a) a single fibre variety (M, B, T and P), and b) two fibre varieties in 1: 1 ratio (MP, BP and TP).

2.2. Methods

2.2.1. Juice extraction

One batch of apple juice was obtained as described in Appendix A and used to prepare the different jelly samples.

2.2.2. Preparation of jellies with and without fibre

Jellies without fibre (control jelly, identified as C) and with fibre (fibre enriched jellies) were elaborated by mixing the ingredients, boiling the mixture, concentrating to 67–69°Brix and bottling, as detailed in Appendix A. Each sample was prepared three times, so that all the following measurements were made in triplicate (except otherwise stated).

2.2.3. Rheological properties

Rheological properties were measured in a Paar Physica MCR 301 rheometer (Anton Paar GmbH, Graz, Austria), using a plate-plate geometry (diameter d = 50 mm, gap = 2 mm), with Peltier controlled temperature. An aliquot of each sample was placed on the rheometer plate at 20.0 ± 0.1 °C. Next, the plate was lowered to the measuring position and excess sample was removed. Elastic (G') and viscous (G'') moduli were determined from dynamic oscillatory measurements at angular frequencies (ω) from 0.1 to 100 rad/s, and at 0.5% strain corresponding to the linear viscoelastic range (LVR) of all samples. Measurements were performed after different storage times: $t_0 = 0$ d, $t_1 = 1$ d, $t_2 = 3$ d, $t_3 = 7$ d, $t_4 = 14$ d and $t_5 = 30$ d.

In addition, the complex modulus (G^*) and the complex viscosity (η^*) of each sample were calculated as:

$$G^* = \sqrt{G'^2 + G''^2} \quad (1)$$

$$\eta^* = \frac{G^*}{\omega} \quad (2)$$

2.2.4. Mechanical properties

Mechanical properties (maximum force (F_{max}), distance of rupture (d^*), force at 3 mm penetration (F_e), adhesiveness (Ad) and gumminess (G) were determined in a TA Plus texture analyser (Lloyd Instruments-Ametek, Albany, USA), applying a penetration test designed for jams (Genovese, Ye, & Singh, 2010) with some modifications, as detailed in Appendix A.

2.2.5. Syneresis

Syneresis was determined as the water loss of the samples during the first 24 h after the texture measurement (at room temperature). The purpose of this was to use samples with damaged structure, as fruit jams present in domestic use (after consumer's extraction from the jar) (Figueroa & Genovese, 2018). Measurements were made at two different storage times (7 d and 30 d), as detailed in Appendix A.

2.2.6. Colour

Colour of the jellies (with or without fibre) was measured in a HunterLab UltraScan XE spectrophotometer colorimeter (Hunter Associates Laboratory Inc., Reston, USA). For each sample, part of the hot jelly was poured in two glass cells (10 mm path) and let cool down during 24 h. Reflected colour (specular component excluded, D65 illuminant, 10° observer angle) was measured. Results were expressed in terms of the CIELab scale parameters: L^* [lightness, 0 = black, 100 = white], a^* [greenness (−), redness (+)] and b^* [blueness (−), yellowness (+)].

2.2.7. Statistical analysis

Experimental data were statically analysed through single-factor Anova tests, and means were compared by Tukey's tests at a significance level of 0.05, using the InfoStat v. 2014 software. In all cases, Box-Cox diagnosis tests were previously performed to check for Anova assumptions (normality and homoscedasticity), and data were transformed when necessary, using Design-Expert v 7.0.0 software.

3. Results and discussion

3.1. Effect of adding a single fibre variety

3.1.1. Rheological properties

Rheological properties of samples C, A, B, W and P at different storage times were analysed. Only in freshly made samples (0 d) values of $G' < G''$ were observed at high frequencies (not shown). This behaviour was mainly attributed to the fact that the product was not completely gelled at the time of the measurement, except sample P that showed a highly thick ("gummy") consistency at the end of the preparation. From 1 d onwards values of $G' > G''$ were observed for all the samples throughout the frequency range (not shown), which means a predominantly solid behaviour (Basu, Shivhare, Singh, & Beniwal, 2011), and indicated that samples were completely gelled after 1 d of cold-storage.

The experimental data of G' vs ω was fitted with the potential function:

$$G' = G'_0 . \omega^n \quad (3)$$

where G'_0 is the predicted value of G' at $\omega = 1$ rad/s and n is the slope of the log G' vs log ω curve.

Calculated values of G'_0, n and R^2 for each sample at the different storage times are shown in Appendix A (Table A1). It should be noted that the log G' vs log ω plot corresponding to 0 d was not linear, so it was not possible to fit it with Eq. (3). Instead, for 0 d the experimental value of G' at $\omega = 1$ rad/s was taken in order to statistically compare all the storage times.

Fig. 1 shows the G'_0 values as function of the storage time. It can be observed that for all samples G'_0 increased over time, and that the greatest change occurred between 0 d and 1 d. This change was significant for all the samples except P (Table A1). From 3 d until 30 d there were no significant changes in the values of G'_0 and n (Table A1). Therefore, it was considered that samples reached an equilibrium gel strength after 3 days of cold-storage, and that their viscoelastic

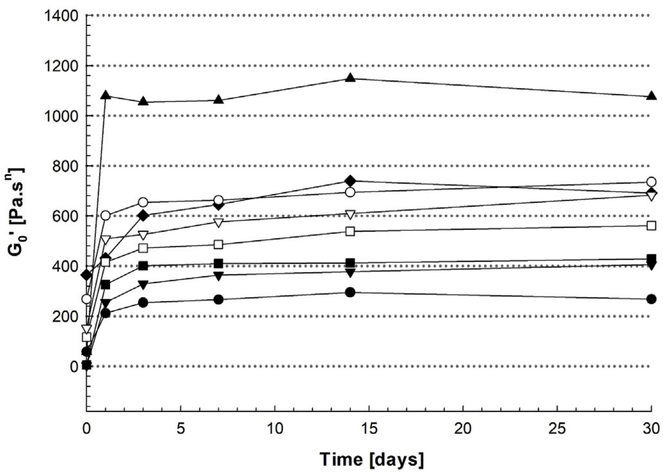

Fig. 1. Elastic modulus coefficient (G′0) vs cold-storage time (t) of the jellies without fibre (●) and with wheat (▼), bamboo (■), psyllium (◆) and apple (▲) fibre, and their combinations in 1:1 ratio: apple-psyllium (○), bamboo-psyllium (□) and wheat-psyllium (▽).

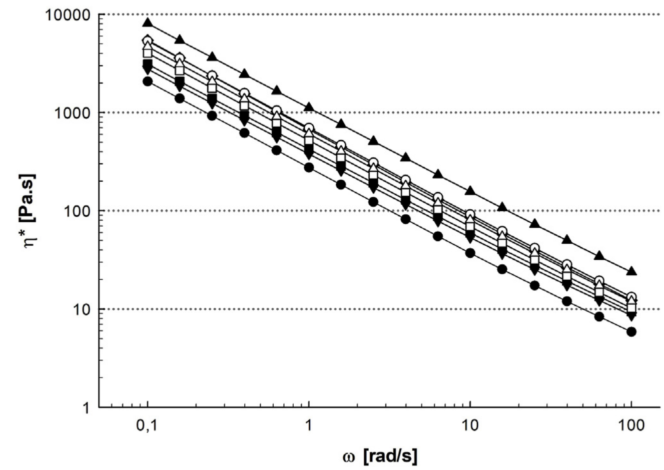

Fig. 3. Complex viscosity (η*) vs angular frequency (ω) of the jellies without fibre (●) and with wheat (▼), bamboo (■), psyllium (◆) and apple (▲) fibre, and their combinations in 1:1 ratio: apple-psyllium (○), bamboo-psyllium (□) and wheat-psyllium (▽).

properties did not change significantly from that moment.

Considering this result, G' and G'' values of each sample from 3 d to 30 d were averaged and represented as a function of the angular frequency (Fig. 2 a y b). In first place, it can be observed that fibre addition to the jelly increased G' and G'' values. For all samples G' increased with the frequency (Fig. 2a), indicating a relaxation process as in fibre enriched gels (Figueroa & Genovese, 2018). All the samples could be described as weak gels, since G' and G'' curves were parallel, $G' > G''$ and both moduli varied with frequency (Ikeda & Nishinari, 2001; Picout & Ross-Murphy, 2003; Seo & Yoo, 2013).

Complex modulus G^* and complex viscosity η^* were calculated with Eqs. (1) and (2), using the mean values of G' and G'' vs ω (Fig. 2 a y b). G^* followed the same trend as G' (not shown). Complex viscosity decreased with increasing angular frequency (Fig. 3), indicating that all samples had a pseudoplastic behaviour, as reported for fruit jams (Basu et al., 2011; Yildiz & Alpaslan, 2012; Álvarez, Cancela, & Maceiras, 2006).

The curves of Fig. 2a were fitted with Eq. (3), obtaining values of G'_0 and n for each sample (Table 1), with regression coefficients higher than 0.992 (not shown). The values of G'' and η^* at a frequency of 1 rad/s were taken as representative of the viscous modulus and complex viscosity of each sample, respectively (Table 1).

It can be observed that fibre addition produced a significant increase in G'_0, in the order: A > P > B > W > C. This was attributed to fibre addition reinforcing the structure of the pectin gel, being likely that the insoluble fraction of the dietary fibre acted as a filler with a reinforcing effect in the gel matrix (Genovese, 2012; Le Goff, Gaillard, Helbert, Garnier, & Aubry, 2015; Wang & Chen, 2017). Fibre addition (except P) caused a significant increase in n. The effect of fibre addition on $G''_{(1\,rad/s)}$ and $\eta^*_{(1\,rad/s)}$ was the same as for G'_0.

A "weak gel" model have been proposed (Gabriele, de Cindio, & D'Antona, 2001) to describe the rheological properties of foods such as doughs, yogurt and fruit jams (Basu et al., 2011). This model is derived from the "gel theory" or Winter theory originally developed for polymers (Power, Rodd, Paterson, & Boger, 1998; Winter & Mours, 1997), which proposes that a "critical gel" is the transition from liquid to solid state, and therefore it relaxes at infinite time and does not flow. Instead, the weak gel model considers foods as gel-like networks capable of flowing, because they have a finite relaxation time. In this model, the gel is seen as a network of strands, constituted by rheological or "flowing units" that do not break or disintegrate during flow, but the strands do. The complex modulus is represented as:

$$G^* = a * \omega^{1/z} \quad (4)$$

Where a may be interpreted as the interaction force between the flow units (which is reflected in the gel strength) and z is called the "coordination number" and is equivalent to the number of flow units interacting with one another and measures the extent of those interactions.

G^* vs ω data (not shown) was fitted with Eq. (4). The fitting values obtained for parameters a and z are listed in Table 1, with regression coefficients higher than 0.983.

It can be observed (Table 1) that fibre addition produced a significant increase in a (gel strength) following the same trend observed for G'_0, $G''_{(1\,rad/seg)}$ and $\eta^*_{(1\,rad/s)}$: A > P > B > W > C. Wheat, bamboo and apple fibre significantly reduced the value of z, while psyllium fibre increased it significantly. This means that the extension of the network or number of interactions decreased in the following

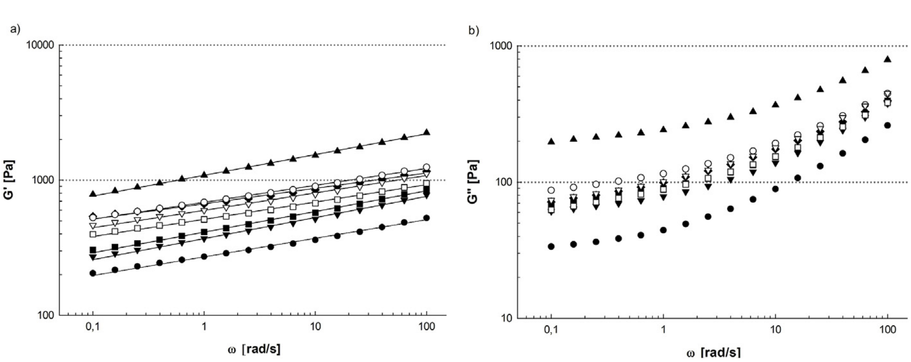

Fig. 2. (a) Elastic modulus (G′) and (b) viscous modulus (G") vs angular frequency (ω) of the jellies without fibre (●) and with wheat (▼), bamboo (■), psyllium (◆) and apple (▲) fibre, and their combinations in 1:1 ratio: apple-psyllium (○), bamboo-psyllium (□) and wheat-psyllium (▽).

Table 1
Elastic modulus (G′$_0$) and exponential (n) coefficients from Eq,(3), viscous modulus (G”$_{(1\ rad/s)}$) and complex viscosity (η*$_{(1\ rad/s)}$) at an angular frequency of 1 rad/s, and interaction force (a) and number of flow units (z) from Eq. (4), obtained for the jellies without fibre (C) and with wheat (W), bamboo (B), psyllium (P) and apple (A) fibre, and their combinations in 1:1 ratio: apple-psyllium (AP), bamboo-psyllium (BP) and wheat-psyllium (WP).

Sample	G$_0$' (Pa.s^n)	n (−)	G” $_{(1\ rad/s)}$ (Pa)	η*$_{(1\ rad/s)}$ (Pa.s)	a (Pa.s$^{1/z}$)	z (−)
C	(271 ± 39) ^{d}	(0.138 ± 0.007) ^{b}	(45 ± 7) ^{d}	(274 ± 40) ^{d}	(274 ± 40) ^{d}	(6.51 ± 0.30) ^{b}
W	(370 ± 110) $^{c,\ E}$	(0.156 ± 0.005) $^{a,\ A}$	(78 ± 25) $^{c,\ D}$	(378 ± 113) $^{c,\ E}$	(376 ± 113) $^{c,\ E}$	(5.85 ± 0.19) $^{a,\ A}$
B	(413 ± 95) $^{c,\ D,\ E}$	(0.151 ± 0.008) $^{a,\ A}$	(90 ± 22) $^{b,\ c,\ C,\ D}$	(423 ± 97) $^{c,\ E}$	(421 ± 97) $^{c,\ E}$	(6.13 ± 0.35) $^{a,\ b,\ A}$
P	(669 ± 81) $^{b,\ B}$	(0.114 ± 0.009) $^{c,\ C}$	(99 ± 5) $^{b,\ B,\ C}$	(676 ± 80) $^{b,\ E}$	(677 ± 80) $^{b,\ B}$	(8.26 ± 0.68) $^{c,\ C}$
A	(1085 ± 264) $^{a,\ A}$	(0.155 ± 0.014) $^{a,\ A}$	(242 ± 45) $^{a,\ A}$	(1111 ± 267) $^{a,\ D}$	(1111 ± 269) $^{a,\ A}$	(6.25 ± 0.59) $^{a,\ b,\ A}$
AP	(686 ± 66) ^{B}	(0.126 ± 0.009) ^{B}	(115 ± 8) ^{B}	(696 ± 66) ^{A}	(695 ± 66) ^{B}	(7.55 ± 0.56) $^{B,\ C}$
BP	(514 ± 69) $^{C,\ D}$	(0.128 ± 0.004) ^{B}	(88 ± 10) $^{C,\ D}$	(521 ± 70) ^{C}	(520 ± 70) $^{C,\ D}$	(7.25 ± 0.21) ^{B}
WP	(598 ± 100) $^{B,\ C}$	(0.131 ± 0.011) ^{B}	(101 ± 12) $^{B,\ C}$	(607 ± 100) ^{B}	(606 ± 100) $^{B,\ C}$	(7.20 ± 0.60) ^{B}

* Samples with a common letter within the same column are not significantly different (p > 0.05). Lower case letters compare the first five samples of the first column (from C to A), upper case letters compare the last seven samples of the first column (from W to WP).

order: P > C > A > B > W. Consequently, it seems that the addition of wheat, bamboo and apple fibre caused a decrease in the number of interactions, but these interactions were stronger. Instead, only psyllium fibre caused an increase in both number and strength of interactions. This could be related to the thick, "gummy" consistency of this sample, and in particular the greater extension of the network interactions could be associated with the higher water retention capacity of the gels with psyllium fibre (Figueroa & Genovese, 2018).

3.1.2. Mechanical properties

The penetration tests were performed at two different storage times, 7 d and 30 d. From the force vs time curves at each storage time (not shown) the mechanical properties were obtained. There was no significant effect of storage time on the texture parameters analysed. For this reason, the data at both storage times was averaged for each sample (Fig. 4), It can be observed that the addition of apple and psyllium fibre (samples A and P) changed considerably the shape of the curve of the control jelly (sample C).

The average values of the mechanical properties obtained for each sample are listed in Table 2. Fibre addition caused an increase in F_{max} in all cases, but it only was significant in the cases of apple and psyllium fibre (samples A and P). This was not due to an increase in the percentage of soluble solids in the samples, as reported by Basu et al. (2011), since our samples had between 67 and 69 g/100 g as indicated in Section 2.2.2, but it was attributed to the contribution of the insoluble fraction of the fibre, reinforcing the structure of the pectin network. On the other hand, it can be observed that only apple fibre

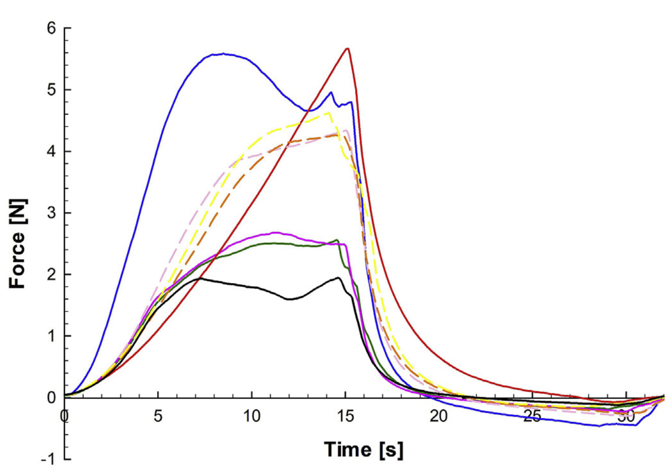

Fig. 4. Force vs time curves obtained from the penetration test of the jellies without fibre (——) and with wheat (——), bamboo (——), psyllium (——) and apple (——) fibre, and their combinations in 1:1 ratio: apple-psyllium (– –), bamboo-psyllium (– –) and wheat-psyllium (– –).

caused a significant increase in F_e, which would indicate that sample A presented the strongest gel, in agreement with G'_0 values (Table 1). On the other hand, no significant differences were found between the d^* values of the samples (Table 2), which indicates that fibre addition had no significant effect on gel's fragility. The only fibre varieties that caused a significant change in adhesiveness compared to the control jelly were apple (increase in absolute value) and psyllium (reduction in absolute value). Finally, apple and psyllium fibre caused a significant increase in the gumminess of the jellies, unlike what was observed in gels (Figueroa & Genovese, 2018). After samples inspection and tasting with lab's staff, it was evident that jellies enriched with psyllium fibre were markedly more "gummy" than the other samples in terms of visual aspect, sense of touch and mouthfeel.

3.1.3. Syneresis

It was found that for each sample there was no significant difference between the syneresis (water loss) measured at 7 d and 30 d (not shown). Therefore, the average value of syneresis at both times was computed for each sample (Table 3).

The addition of apple and psyllium fibre (samples A and P), reduced the syneresis by 50 and 100%, respectively. In other words, sample P did not present any syneresis at all. In contrast, bamboo and wheat fibre (samples B and W) significantly increased the syneresis of the jellies even above 10 g water/100 g product, value proposed as limit of acceptability (Figueroa & Genovese, 2018). This result was different from the one obtained in that work, where bamboo and wheat fibre reduced gel's syneresis, which indicates that in the case of jellies the reinforcing effect of wheat and bamboo fibre was not enough to avoid syneresis. On the other hand, the reduction of syneresis in the cases of apple and psyllium fibre could be associated with the hydration properties of each fibre variety and their contribution to the junction zones formed by the pectin network when gelling.

Results suggests that the fibres that produced a reduction in the syneresis of the jellies (apple and psyllium) were those that more reinforced the structure of the gel, mainly in the terms of parameters G'_0 and F_{max}. Bamboo and wheat fibre also increased these parameters although to a lesser extent, and results indicate their effect on the structure of the gel was detrimental to the syneresis.

3.1.4. Colour

The results of the colour measurements are shown in Table 3. Comparing to the control jelly (sample C), fibre addition significantly decreased the L^* value (darker samples) and this decrease was more noticeable with the addition of apple fibre, which could be due to the presence of polyphenolic compounds and flavonoids in it (Hussein, Kamil, Hegazi N.A., Mahmound, & Ibrahim, 2015). This darkening effect was due to the light scattering produced by the fibre particles added to a translucid medium as jelly, and by particles own colour. This should not be considered as a negative effect, since fibre enriched jellies

Table 2
Maximum force (F_{max}), distance of rupture (d*), force at 3 mm penetration (F_e), adhesiveness (*Ad*) and gumminess (*G*) of the jellies without fibre (C) and with wheat (W), bamboo (B), psyllium (P) and apple (A) fibre, and their combinations in 1:1 ratio: apple-psyllium (AP), bamboo-psyllium (BP) and wheat-psyllium (WP).

Sample	F_{max} (N)	F_e (N)	d* (mm)	Ad (N*s)	G (N)
C	(1.95 ± 0.41) ^{b}	(0.65 ± 0.09) ^{b}	(13.60 ± 3.42) ^{a}	(-0.67 ± 0.16) ^{b}	(0.69 ± 0.12) ^{a}
W	(2.69 ± 0.77) $^{b, C}$	(0.82 ± 0.23) $^{b, B}$	(10.44 ± 0.62) $^{a, B}$	(-1.44 ± 0.61) $^{b, B}$	(0.90 ± 0.20) $^{a, C}$
B	(2.55 ± 1.10) $^{b, C}$	(0.78 ± 0.44) $^{b, B}$	(12.44 ± 2.76) $^{a, A, B}$	(-1.33 ± 0.76) $^{b, B}$	(0.80 ± 0.18) $^{a, C}$
P	(5.79 ± 1.89) $^{a, A}$	(0.59 ± 0.13) $^{b, B}$	(15.02 ± 0.01) $^{a, A}$	(-0.16 ± 0.11) $^{c, A}$	(3.29 ± 1.05) $^{b, A}$
A	(5.76 ± 1.63) $^{a, A}$	(2.29 ± 0.56) $^{a, A}$	(11.73 ± 3.65) $^{a, A, B}$	(-3.80 ± 0.82) $^{a, C}$	(1.79 ± 0.44) $^{b, B}$
AP	(4.46 ± 0.62) ^{A}	(0.91 ± 0.18) ^{B}	(13.71 ± 2.02) $^{A, B}$	(-2.01 ± 0.64) ^{B}	(1.59 ± 0.17) ^{B}
BP	(4.31 ± 0.68) ^{A}	(0.77 ± 0.15) ^{B}	(14.36 ± 1.18) $^{A, B}$	(-1.66 ± 0.49) ^{B}	(1.66 ± 0.26) ^{B}
WP	(4.54 ± 0.74) ^{A}	(0.78 ± 0.17) ^{B}	(14.98 ± 0.04) $^{A, B}$	(-1.17 ± 0.26) ^{B}	(1.67 ± 0.17) ^{B}

* Samples with a common letter within the same column are not significantly different ($p > 0.05$). Lower case letters compare the first five samples of the first column (from C to A), upper case letters compare the last seven samples of the first column (from W to WP).

are similar to fruit jams, which are darker and/or opaquer than jellies due to the presence of fruit pulp. Fibre addition did not have a significant effect on *a**, and it significantly decreased *b** in all cases (less yellowish samples).

In conclusion, it was first observed that samples reached their final consistency or structure after 1 day of elaboration, except samples with psyllium that lasted 3 days. Secondly, fibre addition had a reinforcing effect on the structure or gel strength of the samples. However, psyllium fibre gave a "gummy" appearance to the jellies, which was considered an unfavourable effect. Also, samples tasting with lab's staff showed that addition of wheat and bamboo fibre to jellies left a "floury" sensation to the palate. These fibre varieties also increased the syneresis, so their use alone would not be adequate. With the aim to improve these undesired organoleptic characteristics, pairs of fibre varieties were mixed in equal proportions, taking only those combinations that gave favourable results in gels (Figueroa & Genovese, 2018).

3.2. Effect of the addition of two fibre varieties in the same proportion (1:1 ratio)

3.2.1. Rheological properties

G' vs ω data of the mixtures AP, BP and WP at the different storage times (not shown) were fitted with Eq. (3), and the values of G'_0 and n obtained were represented in Fig. 1 and listed in Table A1. After a significant initial increase of G'_0 between 0 d and 1 d, none of the samples suffered significant changes of G'_0 and n until 30 d (Table A1). Therefore, in order to be able to statistically compare these results with those of Section 3.1.1, experimental data (G' and G'' vs ω) within the same storage period analysed in that section (between 3 d and 30 d) was averaged for each sample.

It can be observed (Fig. 2 a and b) that jellies added with a mixture of fibres (samples AP, BP and WP) also showed a high dependence of G' and G'' with the angular frequency, indicating that they behaved as weak gels, as jellies added with a single type of fibre. Fig. 3 shows that complex viscosity decreased with frequency (as observed in Section 3.1.1), that is, the samples with a fibre combination also observed a pseudoplastic behaviour.

Representative values of the rheological properties G'_0, n, $G''_{(1\ rad/s)}$, and $\eta^*_{(1\ rad/s)}$ (Table 1) of these samples were obtained as in Section 3.1.1. In general, jellies enriched with a fibre combination presented an intermediate rheological behaviour between that of jellies enriched with each corresponding fibre variety (e.g. AP was intermediate between A and P, etc.). Such behaviour was generally dominated by the fibre that had the lowest reinforcing effect.

As in Section 3.1.1, G^* vs ω data (not shown) was fitted with Eq. (4) and a and z parameters of the weak gel model were obtained (Table 1), with regression coefficients higher than 0.988. As expected, the samples with fibre combinations showed intermediate properties (a and z) between the samples with a single fibre variety, following the same trend as G'_0 and $\eta^*_{(1\ rad/s)}$. This indicates that the combination of any fibre with psyllium increased the number and strength of the interactions in the gel.

3.2.2. Mechanical properties

As in Section 3.1.2, no significant differences were found between the texture parameters analysed after 7 d and 30 d of storage. Therefore, for each sample the data at both storage times was averaged. Fig. 4 shows the force vs time curves of the jellies with one fibre variety and with a mixture of two fibre varieties. It can be seen that when the fibres were combined, the curve took an intermediate shape between the curves corresponding to the samples with a single fibre variety. Table 2 shows the mechanical properties obtained from these curves.

In general, it can be said that the combination of psyllium with any other fibre reduced the gumminess compared to the jelly that had only psyllium, in agreement with tasting observations. In addition, the three fibre combinations did not present significant differences among them in any of the analysed texture parameters. This indicates that the mechanical properties of the mixture were governed by psyllium fibre (the

Table 3
Syneresis (g water/100 g product) and colour parameters (L*a*b*) of the jellies without fibre (control, C) and with wheat (W), bamboo (B), psyllium (P) and apple (A) fibre, and their combinations in 1:1 ratio: apple-psyllium (AP), bamboo-psyllium (BP) and wheat-psyllium (WP).

Sample	Syneresis	Colour		
	(g/100 g)	L*	a*	b*
C	(11.69 ± 1.13) ^{b}	(54.69 ± 0.15) ^{a}	(7.57 ± 0.39) $^{a, b}$	(42.0 ± 1.17) ^{a}
W	(15.02 ± 1.12) $^{a, A}$	(33.88 ± 0.85) $^{d, A}$	(6.14 ± 0.85) $^{a, A}$	(23.98 ± 0.63) $^{b, B, C}$
B	(15.05 ± 0.79) $^{a, A}$	(35.29 ± 0.35) $^{c, A}$	(6.24 ± 0.84) $^{a, A}$	(23.0 ± 1.26) $^{b, c, B, C}$
P	0.00 ± 0.00 $^{d, C}$	(30.56 ± 0.06) $^{e, B}$	(9.81 ± 2.90) $^{b, B, C}$	(21.14 ± 0.68) $^{b, c, C, D}$
A	(6.67 ± 0.48) $^{c, B}$	(14.61 ± 2.23) $^{b, C}$	(11.23 ± 1.17) $^{b, B, C}$	(10.47 ± 1.31) $^{d, E}$
AP	0.00 ± 0.00 ^{C}	(16.50 ± 0.54) ^{C}	(14.92 ± 2.43) ^{C}	(19.37 ± 1.09) ^{D}
BP	0.00 ± 0.00 ^{C}	(30.93 ± 0.67) ^{B}	(7.93 ± 0.39) $^{A, B}$	(25.62 ± 1.06) $^{A, B}$
WP	0.00 ± 0.00 ^{C}	(30.44 ± 0.84) ^{B}	(8.12 ± 0.14) $^{A, B}$	(26.16 ± 1.08) ^{A}

* Samples with a common letter within the same column are not significantly different ($p > 0.05$). Lower case letters compare the first five samples of the first column (from C to A), upper case letters compare the last seven samples of the first column (from W to WP).

variety in common in the three combinations), except for the adhesiveness that in all cases was greater in the mixture than in sample P.

3.2.3. Syneresis

There was no significant effect of the storage time on the syneresis values of each sample, so that the experimental data corresponding to 7 d and 30 d were averaged for each sample (Table 3). It can be observed that fibre combination significantly reduced the syneresis of the jellies, since samples AP, BP and WP did not present any syneresis. This was clearly due to the presence of psyllium fibre in the mixtures, since it was the only variety that eliminated the syneresis of the jellies by adding it individually.

3.2.4. Colour

Results of the colour parameters ($L^*a^*b^*$) are presented in Table 3. These results indicate that when a fibre mixture was added to the jellies, the L^* parameter was governed by the fibre variety that gave the darker product when added individually, the a^* parameter of each mixture was not significantly different from that of the jellies with each fibre variety, and the b^* parameter was governed by the fibre variety that gave the most yellowish product when added individually. In conclusion, fibre combinations did not improve the luminosity of the jellies as it happened with the gels (Figueroa & Genovese, 2018), which could be to the fact that gels were prepared with a colourless buffer (transparent) while jellies were prepared based on an apple juice that had a yellowish-brown colour.

Finally, tasting observations indicated that the combination of wheat and bamboo with psyllium improved the palatability of the jellies, reducing the "floury" sensation, and that all samples were organoleptically acceptable. In a future work, a complete sensory analysis with a large number of consumers will be performed on compositionally-optimized samples.

4. Conclusions

It was possible to obtain fruit jellies enriched with dietary fibre, in the concentration required to be declared "source of fibre". This is a novel, stable, functional food product, with potential interest for the food industry. Fibre addition had a reinforcing effect on the viscoelastic and mechanical properties of the jellies. The presence of psyllium fibre completely prevented water loss from the jellies. Combining any of the fibre varieties with psyllium significantly reduced the gumminess of the jelly with psyllium alone, and eliminated the floury mouthfeel of jellies with wheat or bamboo fibres, keeping the syneresis at 0 g/100 g. The possibility of using fibre varieties that were not from fruit origin allowed to increase the insoluble fraction of fibre in the final product.

Declarations of interest

None.

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Appendix A. Supplementary data

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