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Assessing rice flour-starch-protein mixtures to produce gluten free sugar-snap cookies

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Abstract

The mixture of rice flours, starches and proteins is common in gluten-free bakery products such as bread or cake. The aim of this study was to determine the effects of starch and/or protein addition in rice flour gluten-free cookie quality. For this purpose, the hydration and oil absorption properties of flour-starch-protein mixtures, dough rheology and quality cookie parameters (thickness, final diameter, spread factor, texture, colour and acceptability) were analysed. Generally, protein incorporation increased hydration properties of the mixture and dough consistency, producing cookies with limited spreading in the baking time, lower hardness values and darker colour. In particular, protein addition reduced the width up to 8.4% and the hardness up to 10.60 % (control versus 20% of protein inclusion). However, maize starch addition reduced hydration properties and gave rise to cookies with higher thickness and width, but the texture and colour were not affected by the starch. Cookies with higher protein content showed higher acceptability than cookies with higher starch content and no protein addition. Therefore, protein and starch can be used in order to adjust the desired cookie characteristics depending on the cookie formulation and the needs of manufacturers.

Keywords: maize starch; pea protein; dough rheology; cookie texture; sensory analysis.

1. Introduction

Cookies are a baked product that typically has three major ingredients; flour, sugar and fat. There are distinct types of cookies depending on cookie composition, the making of cookie dough and baking parameters. Sugar-snap cookie is a particular type of cookie with high levels of fat and sugar and low water levels characterised by a limited development of the gluten network (Hadnadev, Torbica, & Hadnadev, 2013; Pareyt & Delcour, 2008). In addition, because of the insufficient water content of the cookie dough, most of the starch granules do not gelatinize during the cookie baking process (Pareyt & Delcour, 2008). Due to the minimal gluten development of sugar-snap cookies, there is the possibility to produce gluten-free cookies made from gluten-free flours without any gluten substitute (Donelson, 1988). However, gluten-free flours produce cookies with different physico-chemical characteristics in comparison with cookies made from wheat flour, depending on the cereal origin and the milling process (Mancebo, Picón, & Gómez, 2015).

Most studies that have investigated gluten-free cookies have used different gluten-free flours such as amaranth (de la Barca, Rojas-Martínez, Islas-Rubio, & Cabrera-Chávez, 2010; Gambus et al., 2009; Hozova, Buchtová, Dodok, & Zemanovič, 1997; Tosi, Ciappini, & Masciarelli, 1996; Schoenlechner, Linsberger, Kaczyc, & Berghofer, 2006), buckwheat (Gambus et al., 2009; Hadnađev et al., 2013; Kaur, Sandhu, Arora, & Sharma, 2015: Schoenlechner, Linsberger, Kaczyc, & Berghofer, 2006) and/or rice flour (Chung, Cho, & Lim, 2014; Torbica, Hadnadez, & Hadnadev, 2012) or a mixture of these flours with other cereal flours (maize, sorghum or millet) or legume flours (Altındağ, Certel, Erem, & Konak, 2014; Rai, Kaur, & Singh, 2014). However, many commercial bakery products are mainly made from maize starch mixed, greater or lesser extent, with gluten free flours, starches from tubers and / or proteins. It has been proven that the protein and starch proportion in cookies made from wheat flour play an important role in cookie quality, because of their water absorption capacity, their effect in dough rheology and their spread in the baking process (Pareyt & Delcour, 2008). In general, soft wheat flour, which is characterised by a low protein content and weak gluten strength, is preferred in sugar-snap cookie elaboration (Souza, Kruk, & Sunderman, 1994) since they give rise to cookies with higher spread and cookie set time in the baking process (Kaldy, Kereliuk, & Kozuk, 1993; Miller & Hoseney, 1997). Thereby, starch and protein addition could adjust the expansion in the baking process and gluten-free cookie diameter. It has also been shown that protein content affected dough rheology and texture of cookies, at least in the case of wheat cookies (Gaines, 1990). There are few studies about starch and protein addition in gluten-free cookies. Schober et al. (2003) added starches in gluten-free cookies formulations but they were mixed with three gluten-free flours and only three mixtures were analysed, therefore the effect of starches could not be clearly compared. Sarabhai et al. (2015) studied the effect of protein concentrate (soya and whey protein), however they were added with emulsifiers.

The aim of this study was to determine the effect of the addition of starch and/or protein to rice flour on dough rheology and gluten-free sugar-snap cookies quality.

2. Materials and methods

2.1 Materials

The following ingredients were employed in this study: rice flour (8.01 g/100 g of protein and 74.35 g/100 g starch) provided by Harinera Castellana S.L. (Medina del Campo, Valladolid, Spain), maize starch (DAESANG, Korea), Nutralys F85M pea protein (80 % protein content) (Roquette, Leutrem, France), white sugar (AB Azucarera

Iberia, Valladolid, Spain), margarine 100 % vegetable (Argenta crema, Puratos, Barcelona, Spain), sodium bicarbonate (Manuel Riesgo S.A., Madrid, Spain) and local tap water.

2.2 Methods

2.2.1. Mixture hydration and oil absorption properties

The different flour-starch-protein mixtures were characterised by their hydration and oil absorption properties.

Swelling volume (SV), or the volume occupied by a known weight sample, was evaluated by adding 100 mL of distilled water to 5 g (±0.1 g) of flour sample in a test tube and allowing it to hydrate for 24 h. Water holding capacity (WHC), defined as the amount of water retained by the sample without being subjected to any stress, was determined on the same suspension used to evaluate swelling; the hydrated solid was weighed after removing the excess water and values were expressed as grams of water per gram of solid (AACC method 88-04, 2012). Water binding capacity (WBC), or the amount of water retained by the sample after it has been centrifuged, was measured as described in AACC method 56-30.01 (AACC, 2012). Hydration properties were analysed in duplicate.

The method described by Lin, Humbert, & Sosulski (1974) was used to determine oil absorption capacity (OAC). Flour (100.0 ± 0.2 mg) was mixed with 1.0 mL of vegetable oil. The mixture was stirred for 1 min with a wire rod to disperse the sample in the oil. After a period of 30 min in the vortex mixer, tubes were centrifuged at 3000 × g and 4◦C for 10 min. The supernatant was carefully removed with a pipette and the tubes were inverted for 25 min to drain the oil and the residue was then weighed. The oil absorption capacity was expressed as grams of oil bound per gram of sample on dry basis. Three replicates were performed for each sample. OAC was calculated by Eq. (1):

$$OAC\ (g/g) = Wr / Wi \qquad (1)$$

Where Wr is the residue weight and Wi is the sample weight (g, db)

2.2.2. Cookie preparation

All formulations were prepared using the same quantities of ingredients except for water, which was added to adjust dough moisture content to 15.0 %, and the proportions of flour, starch and protein added (Table 1). The flour-starch-protein mixture moisture was determined by the AACC 44-15.02 method (AACC, 2012). The following ingredients (as g/100 g on dough basis) were used: flour-starch-protein mixture (43.3 g), sugar (31.2 g), margarine (19.4 g), water (5.2 g) and sodium bicarbonate (0.9 g). The margarine and sugar were then creamed at speed 4 for 180 s in a Kitchen Aid 5KPM50 mixer (Kitchen Aid, Benton Harbor, Michigan, USA) with a flat beater, scraping down every 60 s. The water was then added and mixing was continued at speed 4 for 120 s with intermediate scraping. After mixing, the cream was scraped down. Finally, flour and sodium bicarbonate were added, followed by mixing at speed 2 for 120 s, whilst scraping down every 30 s. After mixing, the dough was allowed to stand for a predefined period of 30 minutes. The dough pieces were then laminated with a salva L-500-J sheeter (Salva, Lezo, Spain) (gap width 6.00 mm). Cookie dough was cut with a circular cookie cutter (internal diameter, 40 mm) and weighed. Batches of at least 15 dough pieces were baked in an electric modular oven for 14 minutes at 185ºC. All the cookie elaborations were performed twice.

2.2.3. Dough rheology properties

The rheological behaviour of doughs was studied using a Thermo Scientific HaakeRheoStress 1 controlled strain rheometer (Thermo Fisher Scientific, Schwerte, Germany) and a Phoenix II P1-C25P water bath that controlled analysis temperature (set at 25ºC). The rheometer was equipped with parallel-plate geometry (60-mm diameter titanium serrated plate-PP60 Ti) with a 3-mm gap. After adjusting the 3-mm gap, vaseline oil (Panreac, Panreac Química SA, Castellar del Vallés, Spain) was applied to the exposed surfaces of the samples to prevent them drying during testing. In oscillatory tests, dough was rested for 800 s before measuring. First, a strain sweep test was performed at 25ºC with a stress range of 0.1–100 Pa at a constant frequency of 1 Hz to identify the linear viscoelastic region. On the basis of the results obtained, a stress value included in the linear viscoelastic region was used in a frequency sweep test at 25ºC with a frequency range of 10–0.1 Hz. Values of elastic modulus (G' [Pa]), viscous modulus (G'' [Pa]), complex modulus and tangent δ (G''/G') were obtained for different frequency values (ω [Hz]). Samples were analysed in duplicate.

2.2.4. Cookie properties

The texture of the cookies was measured sixty minutes after baking on eight cookies from each elaboration, using a TA-XT2 texture analyser (Stable Microsystems, Surrey, UK) fitted with the "*Texture Expert*" software. The cookies were broken using the three point bending rig probe (HDP/3PB). The experimental conditions were: supports 30 mm apart, a 20 mm probe travel distance, a trigger force of 5 g and a test speed of 2.0 mm/s.The maximum force (N) and the displacement at rupture (mm) were measured.

Four cookies were weighed and their widths (diameter) and thicknesses were measured with caliper to calculate the spread factor. The diameter of each cookie was measured twice, perpendicularly, in order to calculate an average diameter. The spread factor of the cookies was calculated by dividing the average width by the thickness of the cookies.

Measurements at the centre of the upper surface (crust) colour of six sugar-snap cookies from each elaboration were carried out with a Minolta CN-508i spectrophotometer (Minolta, Co. LTD, Tokyo, Japan) using the D65 illuminant with the 2º standard observer. Results are expressed in the CIE L*a*b* colour space.

2.2.5. Consumer test

Hedonic sensory evaluation of the cookies was conducted with 66 volunteers, staff and students from the Agricultural Engineering College in Palencia (Spain), between the ages of 18–66 and of various socioeconomic backgrounds, who were habitual cookie consumers. Samples were analysed one day after baking. For sensory evaluation, samples were presented as whole pieces on white plastic dishes coded with four-digit random numbers and served in random order. The cookies were evaluated on the basis of acceptability of their appearance, odour, texture, taste and overall appreciation on a nine-point hedonic scale. The scale of values ranged from “like extremely” to “dislike extremely”, corresponding to the highest and lowest scores of “9” and “1” respectively.

2.2.6. Statistical analysis

Differences between the parameters of the different formulations were studied by analysis of variance (ANOVA). Fisher’s least significant difference (LSD) was used to describe means with 95 % confidence intervals. The statistical analysis was performed with the Statgraphics Centurion XVI software (StatPoint Technologies Inc, Warrenton, USA).

3. Results and Discussion

3.1 Mixture characteristics

As can be seen in table 2, protein addition increased every hydration property significantly (WBC, WHC and swelling volume). These results agree with those reported by Traynham, Myers, Carriquiry, & Johnson, (2007) when evaluated the WHC for flour blends. It is well-known that protein has a profound effect on the water absorption properties of the flour when preparing dough, absorbing twice its weight in water, and meanwhile undamaged starch absorbs 33 % of its own weight in water (Manley, 2011). An increase in starch content, reduced WBC, WHC and swelling volume. However, the effect of the starch in WHC and SV was lower than in WBC and the starch effect in WHC and SV was greater as the protein content was increased. The starch effect could be due to high levels of starch in rice flour, and therefore the insignificant differences in total protein content when flour is replaced by starch. In contrast, there were no significant differences in OAC between the different formulas based on the starch or protein addition.

3.2. Dough properties

Dough properties depend on the different ingredients added, such as starch, protein or the water present, and their quantity which in turn influence the handling properties. If the dough is too soft or too firm, it is not easy to handle; the dough must be sufficiently cohesive to hold together during the different processing steps and viscoelastic enough to separate cleanly when cut by the mould (Gujral, Mehta, Samra, & Goyal, 2003). Dough rheological results are shown in table 3. It was observed that elastic moduli (G’) was greater than viscous moduli (G’’) throughout the frequency range for all samples, which suggests a solid elastic-like behaviour of all the cookie doughs studied. Protein addition definitely increased G’, G” and G* values, and decreased tg δ, which agrees with the observations reported by Inglett, Shen & Liu, (2015) when wheat flour was substituted with flours with a higher protein content than wheat flour in cookie. In general, no clear tendency of starch addition was found in dough rheological properties. A positive correlation between dough rheology and hydration properties with a confidence of 99.9 % was found (data not shown), which suggest that the water absorption of the mixture affects the dough rheology.

3.3. Cookie properties

Cookie properties are shown in table 4. No differences were found in cookie moisture content between the mixtures studied, which means that starch and protein did not have any clear effect in this parameter. However, cookie dimensions were affected by the different proportions of flour, starch and protein. On the one hand, thickness and width (diameter) decreased when protein content increased in the formula. In this way, there were no differences observed in spread factor when protein content was modified, since width results were compensated for thickness results. On the other hand, the addition of starch increased cookie thickness and width. Despite this, the resultant dimension for cookies with the higher level of starch studied (60 %) were not representative, since the cookie dough for this formula was excessively sticky and some difficulties were found in the process and it was necessary to add flour in the dough lamination. Just like the incorporation of protein, spread factor was not affected by starch addition, with the exception of the cookie with the highest starch content. The lower dough expansion during the baking process promoted by the protein addition, was also observed by Kaldy et al. (1993) and Miller and Hoseney (1997) in cookies made from wheat flour. It could be related to the protein effect on apparent glass transition temperature which determines the cookie set time (Payret & Delcour, 2008). Another explanation of protein effect on dough expansion could be the higher dough viscosity confirmed by other authors (Hoseney & Rogers, 1994; Miller & Hoseney, 1997). In fact, our study revealed a high correlation between G” values and cookie diameter with 99.9 %

confidence. In addition, a high correlation (99.9 %) between hydration properties of mixtures (WHC, SV and WBC) and cookie diameter was observed. It is in agreement with the results of other authors such as Barrera, Pérez, Ribotta, & León (2007) and Barak, Mudgil, & Khatkar (2014), and it could be related to the dough hydration effect on dough rheology.

Regarding the texture of the cookies, it was found that protein incorporation decreased hardness (maximum breaking strength), which is consistent with the observations of Sarabhai et al. (2015) when incorporated protein concentrates and mixtures of emulsifiers, and the results of Hadnadev et al. (2013) who substituted rice flour with buckwheat flour, which has higher protein content, both in gluten-free cookiesThese authors attributed the lower cookie hardness to changes in the internal structure of the cookies. Conversely, Singh and Mohamed (2007) found no differences in the texture of cookies fortified with gluten or soy protein, which may be due to the wire cut cookie formula used, and especially to the modifications in the water content of the formula based on the farinograph absorption. No clear trend of starch addition was showed in cookie texture. It should be highlighted that texture data of the cookies with the maximum quantity of starch was not representative because of the processing problems already explained. In fact, it was the only cookie that has a significantly larger displacement at rupture and there were no significant differences among the other cookies. No significant correlations between the values of texture and hydration of mixtures or texture and shape cookie (thickness or width) were found, therefore, differences in texture may have been caused by the internal structure.

It was observed that the addition of protein increased a* and b* values of cookie colour. Thereby protein incorporation produced more red-looking and yellow-looking cookies. Protein also reduced L* values on cookies without starch, although this effect was smaller as the amount of starch was increased in the formula. However, including starch hardly influenced the colour of the cookies. The results of the cookies with the maximum quantity of starch (60 % of starch) should not be taken into account, since there were difficulties at lamination and formation and thereby had greater spread ratio, which probably influenced the colour development and give cookies with lower L* values than the others. The higher protein level, and therefore the greatest amount of amino acids can increase the Maillard reactions and therefore the generation of brown compounds, which contribute to the surface colouration of the cookies (Manley, 2011). Other authors found similar effects when they incorporated isolated or concentrated protein in the formulation of cookies (Singh & Mohamed, 2007; Rababah, Al-Mhasneh, & Ereifej, 2006) and when they compared different protein content flours (Mancebo et al., 2015). In contrast, starch had no effect on the colour, it hardly modified the overall proportions of amino acids and / or reducing sugars. The darkening of the cookies can be a positive effect as cookies made from rice flour often have a clearer colour than cookies made from wheat flour (Mancebo et al., 2015). Thereby, the incorporation of protein could minimize these differences.

3.4. Consumer test

After the instrumental analysis of the different cookies, four types of them were selected for a consumer test (Table 5). The cookies made from 100 % rice flour were selected as the control cookies (100-0-0), a cookie with the highest dose of protein but without starch (80-0-20), another with the highest dose of protein and high starch content (30-50-20) and the last cookie without protein but with high starch content (70-30-0). The results of the cookie sensory evaluation are shown in Table 5. Cookies with protein had the best scores for texture and for odour, in this case, when no starch was added. Meanwhile, cookies with starch and without protein got the lowest appearance and texture values. However, this cookie did not show differences in texture with the control cookie. No significant differences in taste between the different cookies were observed. Consumers rated cookies prepared from protein with the highest overall acceptability, although it was not significantly different from the control cookie. However, the cookie with high starch content and no protein got the worst overall acceptability. The higher scores of cookies with high protein content than the scores of cookies made with starch but without protein may be motivated by the darker colour (similar to cookies made from wheat flour) and the lower hardness of these cookies.

4. Conclusion

The substitution of rice flour with protein or starch can help to modify the characteristics of gluten-free cookies. Thus, the incorporation of protein in the formula reduced the size of the cookies (thickness and width), giving rise to less hard and darker cookies. In contrast, starch addition increased the cookie size (thickness and width) without affecting the texture or colour. Starch or protein incorporation did not show a negative effect in sensory evaluation if they are compared with the control cookie. However, it should be taken into account that protein addition modified dough rheology of the cookies, producing more consistent doughs, which could solve problems in cookie lamination and formation if the dough is too soft.

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Figure captions

Figure 1.- Images of gluten-free cookies made from rice flour (F) substituted by maize starch (S) and pea protein (P) with different substitution levels (g/100 g of flour): a) 100 g flour, 0 g starch and 0 g protein (100F-0S-0P); b) 90F-0S-10P; c) 80F-0S-20P; d) 70F-30S-0P; e) 65F-25S-10P; f) 60F-20S-20P; g) 40F-60S-0P; h) 35F-55S-10P; i) 30F-50S-20P.

Table 1.- Experimental design of flour-starch-protein mixtures for preparation of gluten-free cookies

Trials	Mix (F-S-P)	Rice flour*	Maize starch*	Pea protein*
1	100-0-0	100	0	0
2	90-0-10	90	0	10
3	80-0-20	80	0	20
4	70-30-0	70	30	0
5	65-25-10	65	25	10
6	60-20-20	60	20	20
7	40-60-0	40	60	0
8	35-55-10	35	55	10
9	30-50-20	30	50	20

Mix (F-S-P): Mixture of rice flour, maize starch and pea protein (g/100 g of flour)

* g/100 g of flour.

Each mixture was performed in duplicate (n=2)

Table 2.- Flour hydration properties and oil absorption capacity

Mix (F-S-P)	WBC (g water/g solid)	WHC (g water/g solid)	SV (ml/g)	OAC (g oil/g solid)
100-0-0	1.380d	8.8a	1.255b	1.89ab
90-0-10	1.735g	13.4cd	1.815d	1.87ab
80-0-20	2.014i	17.4f	2.315f	1.89ab
70-30-0	1.145b	9.1a	1.235b	1.82a
65-25-10	1.465e	12.0bc	1.670cd	1.84ab
60-20-20	1.790h	14.9e	2.070e	1.91ab
40-60-0	0.930a	8.9a	1.000a	1.92ab
35-55-10	1.300c	11.0b	1.250b	1.88ab
30-50-20	1.700f	14.4de	1.630c	1.96b
Standard error	*0.007*	*0.5*	*0.058*	*0.05*

Mix (F-S-P): Mixture of rice flour. maize starch and pea protein

WBC: Water binding capacity (n=2); WHC: Water Holding Capacity (n=2); SV: Swelling volume (n=2); OAC: Oil Absorption Capacity (n=3)

Mean values followed by the same letter in the same column are not significantly different ($p < 0.05$).

Table 3.- Dynamic oscillatory test results of the dough for gluten-free cookies prepared from mixtures of rice flour, maize starch and pea protein

Mix (F-S-P)	*G' (Pa)*	*G''(Pa)*	*G**	tan δ
100-0-0	148750a	36810ab	153250a	0.25e
90-0-10	278450b	57540cd	284400b	0.21d
80-0-20	672500e	94035ef	679350e	0.14a
70-30-0	105465a	28960a	109750a	0.28f
65-25-10	218400b	47730bc	223750b	0.22d
60-20-20	509400d	84410e	516500d	0.17b
40-60-0	107450a	28010a	111150a	0.26e
35-55-10	355500c	66595d	362250c	0.19c
30-50-20	712200e	101195f	720000e	0.14a
Standard error	*19974*	*3701*	*20192*	*0.01*

Mix (F-S-P): Mixture of rice flour. maize starch and pea protein (g/100g of flour)

G': elastic moduli; G": viscous moduli; G*: complex moduli; tan δ: tangent delta.

Mean values (n = 4) followed by the same letter in the same column are not significantly different ($p < 0.05$).

Table 4.- Quality parameters of cookies based on rice flour, maize starch and pea protein

Mix (F-S-P)	Moisture (%)	Thickness (mm)	Width (mm)	Spread	F max (N)	Distance (mm)	L*	a*	b*
100-0-0	2.76ab	8.87c	44.27c	4.99a	28.30d	0.34a	78.63e	0.67a	22.73bc
90-0-10	3.29bc	8.01b	42.57b	5.32a	27.26cd	0.37a	76.63cd	4.55b	23.17c
80-0-20	2.77abc	7.32a	40.52a	5.53a	25.30bc	0.34a	73.94b	6.77d	26.68d
70-30-0	2.93abc	9.59d	48.56d	5.06a	28.25d	0.41a	77.95de	0.22a	20.21ab
65-25-10	2.47ab	8.72c	44.29c	5.08a	22.82a	0.34a	77.10cde	3.89b	23.49c
60-20-20	3.88c	8.05b	42.11b	5.23a	25.43bc	0.37a	75.18bc	5.61c	26.23d
40-60-0	2.51ab	7.16a	57.98e	8.15b	24.03ab	0.57b	70.95a	0.82a	19.61a
35-55-10	1.86a	9.76d	47.86d	4.90a	27.01cd	0.36a	76.70cd	3.97b	22.92c
30-50-20	3.12bc	8.57bc	44.44c	5.19a	22.37a	0.35a	77.01cde	5.69c	23.40c
Standard error	*0.35*	*0.20*	*0.49*	*0.25*	*1.52*	*0.04*	*0.60*	*0.22*	*0.81*

Mix (F-S-P): Mixture of rice flour. maize starch and pea protein (g/100 g of flour)

Spread (width/thickness). F max (N): The maximum force (N); Distance: displacement at rupture (mm)

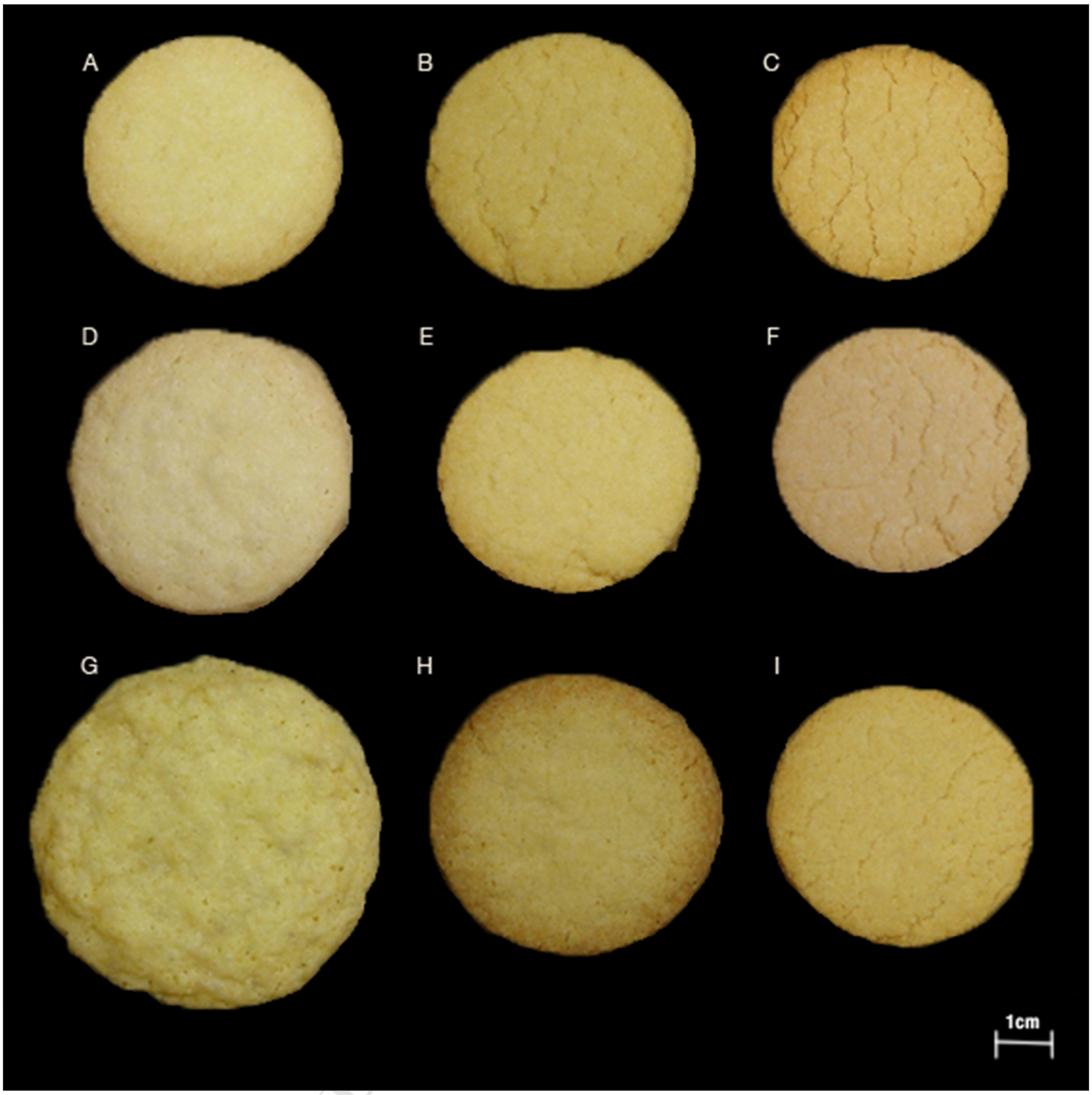
Mean values (n=2) followed by the same letter in the same column are not significantly different ($p < 0.05$).

Table 5.- Consumer test results of cookies based on rice flour, maize starch and pea protein

Mix (F-S-P)	Appearance	Odour	Texture	Taste	Overall acceptability
100-0-0	6.06b	5.68a	5.26ab	5.68a	5.73ab
80-0-20	5.91b	6.22b	5.77bc	5.80a	5.98b
70-30-0	5.29a	5.42a	4.86a	5.32a	5.23a
30-50-20	6.44b	5.59a	5.97c	5.68a	5.92b
Standard error	*0.20*	*0.18*	*0.20*	*0.21*	*0.19*

Mix (F-S-P): Mixture of rice flour. maize starch and pea protein (g/100 g of flour)

Mean values (n=66) followed by the same letter in the same column are not significantly different ($p < 0.05$).


A
B
C
D
E
F
G
H
I
1cm

Highlights

Protein addition increased hydration properties of the mixture and dough consistency

Starch addition increased cookie dimensions without affecting the texture or colour

Protein content reduced the cookie dimensions and hardness and boosted darker cookies

Starch or protein incorporation did not affect sensory acceptability