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Incorporation of xanthan gum to gluten-free pasta with cassava starch. Physical, textural and sensory attributes

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ABSTRACT

Our aim was to develop gluten-free pasta from a formulation with cassava starch and corn flour (proportion 80:20) and the incorporation of xanthan gum (XG) at different concentrations to optimize it (0.4; 0.6 and 0.8%). The optimal concentration of XG in the pasta was determined from cooking and textural quality, protein, color and sensorial analysis. XG improved the handling of the dough and the properties of the pasta, producing substantial changes in the physical and textural properties. The results showed that 0.6% XG concentration developed the highest potential to improve the pasta capacity to prevent structure disintegration with the lowest cooking loss and the lowest values for firmness, cohesiveness, chewiness, springiness and cutting force. We also got as a result some yellowish pasta with firm and long strands, non-adhesive mouthfeel and an increment in protein content as compared to control. These attributes enabled us to elaborate pasta from a high proportion of cassava starch.

1. Introduction

In the search of satisfying sectors of the population with food intolerance and allergies such as wheat allergy, gluten intolerance and celiac disease, the development of new products based on the inhibition of using wheat flour, oats, barley and rye, lead to the need of knowing their physical, textural and sensorial properties in order to reach the consumer's acceptance. Significant advances have been reported in the development and evaluation of pasta elaborated from mixtures that use different flours: amaranth, chickpea, broad beans, beans, corn, rice, cassava, quinoa, among others, (Larrosa, Lorenzo, Zaritzky, & Califano, 2016; Loubes, Flores, & Tolaba, 2016; Rosa-Sibakov et al., 2016; Sirirat, Charutigon, & Rungsardthong, 2005; Yalcin & Basman, 2008).

Pasta has a high acceptance around the world and it is easy to prepare, but the lack of gluten leads to fragile and crumbly dough with poor processability, therefore it poses a big problem to the food industry (Cai et al., 2016). In general, the use of starches, gums or hydrocolloids are the means used to make the gluten replacement. The most used hydrocolloids for food formulation are guar gum (GG), xanthan gum (XG), hydroxypropyl methylcellulose (HPMC), carboxilmetilcelulosa (CMC), (Ko, Kim, Baek, & Park, 2015; Larrosa et al., 2016; Palavecino et al., 2017; Susanna & Prabhasankar, 2013; Choy, May, & Small, 2012), among others.

Several authors (Edwards, Biliaderis, & Dexter, 1995; Sozer, 2009) reported that among the gums used in the farinaceous industry, xanthan gum is the chosen one because it improves the final product, which contributes to its acceptance. The Argentine Food Code (CAA), in Chapter XVIII (Food Additives), states that the maximum amount of XG to add in pasta with egg is 1% (w/w).

Cassava starch, which is widely produced in Misiones (Argentine), is an option to replace wheat flour, but it is underused in the food industry. It is used in small proportions in products for celiac' diets in mixtures with other flours (López, Pereira, & Junqueira, 2004). To give added value to this raw material, we proceeded to strengthen its incorporation to other kinds of food.

The objective of the work was to analyze the effect of the incorporation of xanthan gum to pasta with high proportion of cassava starch in its formulation from the cooking and texture properties, and verify the textural sensorial characteristics of the products with the best technological results.

Abbreviations: XG, Xanthan gum; OCT, Optimum cooking time; CTRL, Control pasta without XG; F1, pasta with 0.4% XG; F2, pasta with 0.6% XG; F3, pasta with 0.8% XG

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2. Materials and methods

2.1. Materials

All ingredients used for pasta elaboration were purchased in local markets. They are gluten-free national brands (Argentine). Dough was elaborated using traditional methods from bread formulations (Milde, González, Urbina, and Rybak (2009); Milde, Ramallo, and Puppo (2012)). Their preliminary assays to obtain the optimum mixture resulted with cassava starch (Montecarlo®, Misiones) and corn flour (Indelma®, Santa Fe) in an 80:20 ratio, whole milk powder (Ilolay®, Santa Fe), salt (Dos Anclas®, Buenos Aires), vegetable fat (Margadan®, Buenos Aires) and whole fresh egg. The additive, xanthan gum (Parafarm®, Buenos Aires) was used.

2.2. Pasta processing

Pasta was elaborated with an own formulation (Milde et al., 2009) optimized for their production, composed of cassava starch and corn flour, whole milk powder; salt; xanthan gum (XG). To this solid mixture, vegetable fat, whole fresh egg and water were added to form homogeneous dough that allowed its lamination and cutting (spaghetti) with a laminator (Pluselectric®, China). A unifactorial design of XG concentration at 3 levels was selected (0.4, 0.6 and 0.8%), to analyze the behavior of the ingredients in order to guarantee an easy handling of the dough and a final product accepted by consumers. Control pasta was prepared without XG (0%). Details of the pasta formulation are provided in Table 1.

2.3. Cooking quality

The optimal cooking time (OCT) for each formulation was determined by the disappearance of the opaque line in the center of the pasta (AACCI Method 66-50.01).

Once the OCT was evaluated by triplicate, each pasta sample was cooked and the solid loss and water absorption during cooking were determined by the AACCI Method 66-50.01. The loss of solids in the cooking water collected from each sample was determined by evaporation in a hot air oven at 105 °C for 24 h. The residue was weighed and reported as percentage of the original pasta sample.

The water absorption of drained pasta was determined as (weight of cooked pasta) – (weight of raw pasta)/(weight of raw pasta) x 100.

2.4. Texture quality

Texture quality was analyzed in a TAXT2i Texture Analyzer (Stable Micro Systems, UK). For every formulation, ten repeated measurements were done and mean values and standard deviations were reported. Measurements were carried out on cooked samples. The data were analyzed with Texture Exponent software version 1.22 (Stable Micro Systems).

2.4.1. Cutting force

This test was used to determine the maximum force (N) needed to cut the cooked pasta. Each analysis was carried out on five strands of cooked spaghetti at room temperature (25 °C) using the Light Knife Blade A/LKB probe to simulate the biting of incisive teeth (speed = 0.17 mm/s). Cutting force was calculated as the area under the curve of the force (N) versus time (s) graph obtained from the software.

Table 1
Formulation of pasta composed of cassava starch and corn flour in 80:20 ratio. (g/100g).

Pasta	Whole milk powder	Salt	Vegetable fat	Whole egg Fresh	XG
CTRL	7	0.5	3.5	31	0
F1	7	0.5	3.5	31	0.4
F2	7	0.5	3.5	31	0.6
F3	7	0.5	3.5	31	0.8

XG: Xanthan gum. CTRL: Control pasta without XG; F1: pasta with 0.4% XG; F2: pasta with 0.6% XG; F3: pasta with 0.8% XG.

2.4.2. Texture profile analysis (TPA)

The texture of cooked pasta was determined with a two compression cycles test using a 50 kg load cell and equipped with compression platens (P/75). The pre-test speed was 1 mm/s, while the test speed was set on 0.5 mm/s, and the strain was 50%. The sample to be evaluated was standardized by cutting strips of cooked pasta of 4 cm long. The sample was placed on the base and it was compressed twice to give a two complete compression-relaxation-tension profile curve. From the force–distance curve, firmness (N) adhesiveness (N.s), springiness, cohesiveness and chewiness were obtained, according to definitions by Martinez, Ribotta, Leon, and Anon (2007).

2.5. Protein determination

The nitrogen content was determined by using the Kjeldahl method and it was multiplied by a factor of 6.25 to determine the protein content; the moisture contents were determined according to AACC approved method (2000). Three replicates of each cooked sample were analyzed.

2.6. Color analysis

The color of cooked pasta was measured with HunterLab Miniscan colorimeter (model EZ 4500 L, Hunter Associates Laboratory Inc., Reston, VA), calibrated by using white and black standards. Color readings were expressed by CIE LAB values for L*, a* and b*. L* values measure black to white (0–100), a* values measure redness when positive and greenness when negative, and b* values measure yellowness when positive and blueness when negative. Three replicates of each sample were analyzed.

2.7. Sensory evaluation

Sensory evaluation of pasta was carried out through two analytical tests: Triangle Test (AACCI Method 33–50.02) and Intensity Test, by eight semi-trained judges (three males and five females, three of whom were celiac), for comparative and descriptive evaluation of the quality between two samples with different concentrations of XG chosen after analyzing cooking and texture parameters It was performed by Facultad de Ciencias Exactas, Químicas y Naturales de la Universidad Nacional de Misiones. Pasta was cooked in boiling water with salt, to OCT and 20 g were placed in thermal plastic cups with butter to simulate the way in which pasta is usually consumed. All samples were presented to each judge in a random order, identified with three numbers. The attributes were evaluated in a way that was prepared for the test. Drinking water was provided for mouth cleansing between each sample.

In the Triangle Test the judges identified among 3 samples (2 were the same). In the Intensity Test the judges evaluated the sensory attributes of the samples, one at a time: hardness (the force required to compress the cooked pasta when placing it between the molars pressing slightly; adhesiveness (the force required to remove the adhering food from the palate) and chewiness (amount of movements necessary for the product placed between the molars to be ready to be swallowed. Definitions of attributes were adapted from Torricella Morales, Zamora, and Pulido (2007). Each attribute was evaluated on a 7-point scale (range from very low to very high). Tests were carried out in triplicate.

Table 2
Quality characteristics of the gluten free pasta. Means and standard deviations of cooking loss, water absorption.

Pasta	OCT (min)	Water absorption (%)*	Cooking loss (%)*
CTRL	7.0	211.3 ± 2.4[a]	15.0 ± 1.0[a]
F1	5.0	114.2 ± 1.8[b]	8.4 ± 0.8[b]
F2	5.0	157.0 ± 1.8[c]	5.4 ± 0.6[c]
F3	7.0	147.3 ± 10.1[c]	5.4 ± 0.6[c]

*Different letters in same column show significant difference among the values of mean value ± standard error ($P < 0.05$).
OCT: Optimal Cooking Time. CTRL: Control pasta without XG; F1: pasta with 0.4% XG; F2: pasta with 0.6% XG; F3: pasta with 0.8% XG (XG: Xanthan gum).

2.8. Statistical analysis

The results were reported as means and their standard deviations. The means of the parameters (cooking and texture quality, color and proteins) were examined for significant differences by analysis of variance (ANOVA) and differences between group means ($P < 0.05$) were analyzed by Fisher's test using Statgraphics software plus 5.1.

In the Triangle Test the one-sided binomial table (Roessler, Pangborn, Sidel, & Stone, 1978) was used because only one sample was different; for the Intensity Test, a score to each category of the scale (1 to the lowest and 7 to the highest) was assigned and plotted in a radar graphic To determine the significances within treatments, Fisher's multiple range test was used.

3. Results and discussion

3.1. Cooking quality of pasta

The OCT is shown in Table 2.

Gluten-free pasta analyzed by other authors (Sabbatini, Sánchez, De la Torre, & Osella, 2015; Susanna & Prabhasankar, 2013), presented similar OCT values, ranging between 5 and 5.5 min. The reduction of the OCT, with reference to pasta elaborated from wheat flour or wheat semolina, can be attributed to the accelerated softening process of the pasta that, because of the absence of gluten, loses its ability to maintain mechanical properties in the presence of water (Phongthai, D'Amico, Schoenlechner, Homthawornchoo, & Rawdkuen, 2017).

Cooking time is the parameter that determines the time pasta needs to be in contact with boiling water to be cooked and consumed. Through cooking, proteins are denatured, complete gelatinization of the starch occurs, the granule undergoes transformations that go from the loss of the crystalline structure without rupture of the granule to dextrinization and leaching (Palavecino et al., 2017). These transformations of the starch depend on several factors such as: concentration, level of mechanical stress during the cooking process, treatment time.

In water absorption and cooking loss, significant differences ($p < 0.05$) were obtained between the CTRL and F1, F2 and F3 pasta. When CTRL pasta is cooked, it absorbs a high quantity of water with greater loss of solids (Table 2), possibly due to the fact that the structure is formed by ovo-lacto proteins which are weaker than traditional wheat flour pasta (Doxastakis et al., 2007). Some soluble components such as amylose, non-starch polysaccharides and proteins can be left in the cooking water (Malcolmson & Matsuo, 1993). Incorporating XG to the formulation, would help in the formation of a stronger network, in which starch granules would be trapped. At a lower concentration of XG (F1) we observed that it was not enough to form an appropriate network, which was reflected in the high cooking loss. At higher concentrations (F2 and F3) there were no significant differences ($P > 0.05$); in both parameters we deduced that a strong three-dimensional polymer network was formed when the dough was elaborated and that prevented the solids diffusion (Marti & Pagani, 2013).

Different authors (Sirirat et al., 2005; Susanna & Prabhasankar, 2013; Yalcin & Basman, 2008) elaborated gluten-free noodles with different flours and XG (and other additives) at similar concentrations or higher than those used in the present work (between 0.5% and 3%), and they obtained varied results in both parameters; which could be justified by the nature of the formulations.

According to Loubes et al. (2016) low amounts of residues indicate high quality pasta cooked and it should have values less than 9% (Astaíza, Ruíz, & Elizalde, 2010). From the formulation with XG analyzed we obtained good quality pasta; the cooking loss values of the present study were lower than those gluten-free noodles reported by other authors (Larrosa et al., 2016; Loubes et al., 2016).

Water absorption during pasta cooking is mainly a function of the protein content and according to Palavecino et al. (2017), starch gelatinization occurs inward and it occurs at a rapid rate at low protein concentrations. In gluten-free pasta, where the protein content is low, the presence of XG in dough formulation causes a polymer network to be formed between protein chains and hydrocolloids; it traps the starch granules during cooking and restricts excessive swelling and amylose diffusion (Edwards et al., 1995).

3.2. Texture quality

Texture of the cooked pasta is considered as the most critical characteristic in the evaluation of the quality of pasta and its acceptance by the consumer (González, McCarthy, & McCarthy, 2000). The incorporation of XG produced a statistically significant difference ($P < 0.05$) with a considerable increase in the values of most of the texture parameters analyzed (Table 3).

The firmness values of the pasta increased with the addition of XG, its presence improved the blending of the ingredients of the dough. This is necessary from the technological point of view with this raw material, to obtain dough able to resist industrially the efforts necessary to be processed, fulfilling a function similar to gluten. In absence of XG, the pasta broke even before cooking.

F1 and F2 pasta did not show significant statistical differences ($P > 0.05$) in the parameters firmness, adhesiveness and cutting force; where there were differences ($P < 0.05$) F2 obtained the lowest values (Table 3). F3 showed marked differences with the other pasta causing undesirable effects (greater firmness, cutting force and chewiness).

Researchers (Padalino, Mastromatteo, De Vita, Maria Ficco, & Del Nobile, 2013; Sudha & Leelavathi, 2012; Yalcin & Basman, 2008) presented the same tendency in cutting force when they studied formulations with different flours and additives. The same happened to Prabhasankar, Rajiv, Indrani, and Rao (2007) when they worked with

Table 3
Quality textural characteristics of the gluten free cooked pasta expressed as the mean value and standard deviations.

Pasta	Firmness (N)*	Adhesiveness (N.s)*	Springiness*	Cohesiveness*	Chewiness*	Cutting force (N.s)*
CTRL	3.2 ± 0.2[a]	0.1 ± 0.0[a]	0.9 ± 0.0[a]	0.7 ± 0.0[a]	1.8 ± 0.2[a]	1.6 ± 0.05[a]
F1	6.9 ± 0.6[b]	0.2 ± 0.1[b]	0.9 ± 0.0[a]	0.6 ± 0.0[b]	3.9 ± 0.5[b]	2.7 ± 0.1[b]
F2	6.5 ± 0.4[b]	0.2 ± 0.0[b]	0.8 ± 0.0[b]	0.61 ± 0.03[c]	3.1 ± 0.3[c]	2.4 ± 0.3[b]
F3	7.8 ± 0.7[c]	0.2 ± 0.0[b]	0.82 ± 0.03[ab]	0.6 ± 0.0[b]	4.1 ± 0.5[b]	3.7 ± 0.2[c]

*Means with different letters in the same column differ significantly at $P < 0.05$.
CTRL: Control pasta without XG; F1: pasta with 0.4% XG; F2: pasta with 0.6% XG; F3: pasta with 0.8% XG (XG: Xanthan gum).

semolina from durum wheat with whey protein concentrate and additives.

The firmness values were incremented when XG was added; Larrosa, Lorenzo, Zaritzky, and Califano (2013) concluded that XG helped to imitate the elastic texture of gluten and to improve firmness in their pasta. Other authors found a similar tendency to incorporate various additives in their formulations (Cai et al., 2016; Palavecino et al., 2017; Zhou et al., 2013). Raina, Singh, Bawa, and Saxena (2005) reported that hydrophilic components of hydrocolloids interact with proteins due to ionic charges and improve the structure of the pasta. On the contrary, researchers (Kaur, Shevkani, Singh, Sharma, & Kaur, 2015; Lai, 2001) worked with wheat flours and obtained a decrease in firmness with the addition of additives (GG, XG, others).

The cohesiveness values of the pasta decreased, but this did not happen to the adhesiveness when XG was incorporated to the formulation. According to some authors (Larrosa et al., 2016; Sozer, Dalgıç; Kaya, 2007), cohesiveness can be an indicator parameter of how the matrix is held together during cooking, and adhesiveness is related to the amount of starch granules that exude from the pasta matrix to the cooking water and cover the surface of the product.

According to Sozer, Dalgıc, and Kaya (2007) with the cooking severe modifications occur in the microstructure of the pasta, loss of uniformity and changes by the diffusion of water from the outside to the core. Closer to the surface, the changes are more drastic. Some researchers obtained similar results in both parameters when they studied pasta with and without gluten with additives (Kaur et al., 2015); in cohesiveness (Choy et al., 2012; Ko et al., 2015) and in adhesiveness (Cai et al., 2016; Larrosa et al., 2016; Padalino et al., 2013; Zhou et al., 2013).

The chewiness is the combination of three important texture parameters and, therefore, it is a vital response to be evaluated during the gluten-free pasta formulation. It is related to the elastic resistance of the structure and generally decreases with the leaching of the starch in the cooking water (Sozer et al., 2007). In the present study, the chewiness increased when XG was incorporated. This corresponds to the results obtained from lower solid loss; while in the springiness it did not influence significantly, except in F2 with decrease in its values. Similar results were found in both texture parameters by Rosa-Sibakov et al. (2016); in chewiness (Cai et al., 2016; Palavecino et al., 2017); in springiness (Ko et al., 2015).

F2 and F3 pasta did not present significant differences ($P > 0.05$) in the parameters of cooking quality (water absorption and cooking loss); in textural parameters, better results were obtained with F2 (lower value of springiness, chewiness and cutting force). F1 and F3, did not present significant differences in some texture parameters (adhesiveness, cohesiveness, springiness and chewiness), so it would not be justified to add a higher concentration of XG.

3.3. Proteins

The protein content in the pasta is shown in Table 4.

The incorporation of XG did not produce statistically significant difference ($P > 0.05$) between CTRL and F1 pasta. Difference was obtained with F2 ($P < 0.05$) because higher XG concentration would help in the formation of a stronger network, wich would retain proteins and derive in increasing values (Table 4). This result is related to the ones obtained in solids loss. Protein value (5.5%) was similar to that found by Palavecino, Ribotta, León, and Bustos (2019) when analyzed soy pasta (6%), corn pasta with vegetables (5.2%) and higher than rice pasta (2.2%). Padalino et al. (2013) obtained the same results, protein content increased with the addition of other additives (guar, gelatin, chitosan) when it is analized compared to gluten-free pasta without additives. Susanna and Prabhasankar (2013) did not observe statistical differences between gluten-free pasta without additives and with XG, possibly due to the use of flours with high protein content.

Table 4
Means and standard deviations of the moisture and protein content in cooked pasta to each OCT.

Pasta	Moisture (g/100g)	Protein (% b.s.)*
CTRL	74.4 ± 0.5	4.7 ± 0.1[a]
F1	76.9 ± 0.1	4.6 ± 0.1[a]
F2	73.4 ± 0.5	5.5 ± 0.6[b]

*Different letters in same column show significant difference among the values of mean value ± standard error ($P < 0.05$).
CTRL: Control pasta without XG; F1: pasta with 0.4% XG; F2: pasta with 0.6% XG (XG: Xanthan gum).

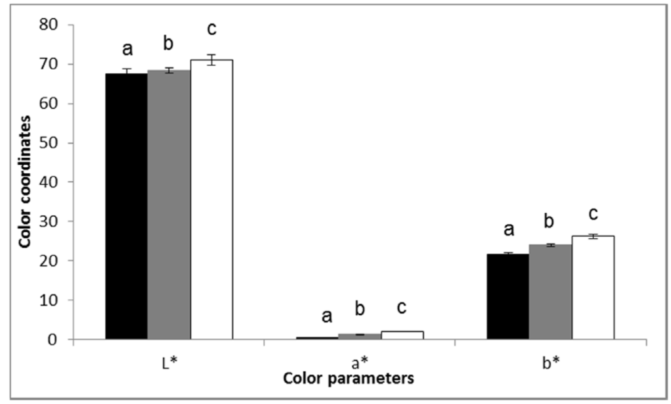

Fig. 1. CTRL: Control pasta without XG (black bars); F1: pasta with 0.4% XG (gray bars); F2: pasta with 0.6% XG (white bars); XG: Xanthan gum. Color parameters: L* (lightness), a* (green-red) and b* (blue-yellow) in cooked pasta. Bars represent ± standard deviation; different letters in each column indicate significant differences ($P < 0.05$) between samples.

3.4. Color

The color parameters of gluten-free pasta samples are shown in Fig. 1.

Fig. 1 shows that the incorporation of XG produced significant differences ($P < 0.05$) in pasta analyzed with respect to control and between different concentrations of XG, with increase in the values of all color parameters. L* and b* are considered the most important parameters as color attributes for pasta elaborated with eggs (Martinez et al., 2007). The results indicate that the incorporation of XG makes the color of the noodles brighter (increased L* values) and yellowish (observe the b* values), wich are the qualities preferred by consumers. The same results were obtained by Srikaeo, Laothongsan, and Lerdluksamee (2018) when they elaborated dry rice noodles with additives (CMC, XG and GG) at two levels 0.05% and 0.1%. However, Choy et al. (2012) produced wheat noodles with the addition of CMC (0.5 and 1%) and observed a decrease in the three color parameters.

3.5. Sensorial

To evaluate the optimal XG concentration for the studied formulations, a sensory analysis was carried out between F1 and F2 pasta.

Triangle Test: To evaluate the results, the significance test was used with the statistical table for the triangle test, the correct answers from the judges ($n = 19$) and the total answers ($X = 24$); and significant differences ($P < 0.05$) were observed.

Intensity test: Fig. 2 shows the results obtained from the sensory test of intensity evaluation of the textural characteristics of the pasta studied.

Statistically significant differences were observed between both samples in the chewiness values ($P < 0.05$). In hardness, there were no significant differences but a higher score was obtained for F2. At higher

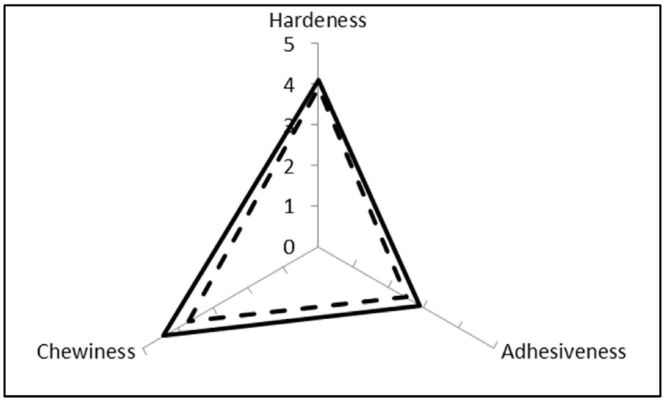

Fig. 2. Results from the sensory test of intensity of texture attributes of cooked pasta. F1: pasta with 0.4% XG (continuous line); F2: pasta with 0.6% XG (dashed line); XG: Xanthan gum.

concentration of XG (F2), the pasta remained firmer after cooking (good indicator of pasta quality), although the chewiness was higher because it was directly related to hardness values. The scores obtained in adhesiveness were low and very similar between both samples, a characteristic very common in pasta elaborated from flours other than wheat (Marti & Pagani, 2013).

Cai et al. (2016) obtained a similar behavior when evaluating the intensity of these parameters in samples of noodles elaborated with different gluten-free flours with XG using a sensory panel.

4. Conclusions

Gluten free pasta production requires an additive to act as a binder, since its proteins lack the functionality of wheat gluten in making a cohesive dough structure. Xanthan gum improved the handling of the dough and the properties of the final product. It produced substantial changes in the physical and textural properties of this pasta elaborated with high proportion of cassava starch. The 0.6% xanthan gum concentration developed the greatest potential to improve the pasta since it decreased cooking loss and presented the lowest values for the texture parameters: firmness, cohesiveness, chewiness, springiness and cutting force. With the sensorial test results of the analytical type, we concluded that it was an appropriate choice. However, protein fortification and drying of pasta should be evaluated for the development of this cassava starch based gluten-free pasta in a commercial scale.

Author Contributions

Laura Beatríz Milde: Master, conceptualización, conservación de datos, análisis formal, adquisición de fondos, investigación, metodología, administración de proyectos, recursos, software, supervisión, validación, visualización, redacción - borrador original, redacción - revisión y edición. Paola Soledad Chigal: Formal analysis, Investigation, Methodology, Writing - review & editing. Jorge Emiliano Olivera: Formal analysis, Investigation, Methodology, Writing - original draft. Karina Grissel González: Formal analysis, Investigation, Methodology, Writing - original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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