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Viscoelastic Characterization of Pasta Dough Supplemented of Cassava Bagasse and Hydrocolloids

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Abstract

Objective: To develop fiber-rich pasta by partially replacing wheat semolina with cassava bagasse and incorporation Carboxymethylcellulose (CMC). **Methods/Analysis:** Pasta was made with cassava bran (10, 20 and 30% w/w) and carboxymethylcellulose - CMC (0.5, 1 and 1.5% w/w). A rheological characterization of the products was carried out. The pasta that presented the best rheological characteristics was subjected to a sensory analysis to determine its degree of acceptance. **Findings:** Partial replacement of wheat semolina by cassava bagasse and the addition of Carboxymethylcellulose showed predominance of storage modulus over loss modulus in dynamic oscillatory tests and, In addition, by increasing the bagasse content of cassava and hydrocolloid a predisposition of increase in the modules was observed, probably associated with the effect fiber has on water absorption, generating a more solid dough and the ability of this hydrocolloid to mimic viscoelastic properties of gluten. Sensory characterization of pasta decreased with the increase in cassava bagasse content, however, adding the hydrocolloid improved its quality. **Novelty:** Incorporation of cassava bagasse in pasta is an alternative to improve its nutritional composition by increasing its fiber content.

Keywords: Fiber, Hydrocolloid, Sensory, Viscoelasticity

1. Introduction

Cassava is a plant of integral use since its roots and leaves are source of carbohydrates and proteins; roots are used for human diet as fresh food, croquettes, flour and starch; in animal feed it is used as a supplement in concentrates for poultry, pigs and ruminants; and at industrial level in obtaining starch, flour, alcohol fuel, gum, adhesives, dextrin, glucose, among others[1].

In the process of obtaining cassava starch, waste harmful to the environment is generated, mainly husk, wastewater, and cassava bagasse[2]. Its incorrect disposal represents a loss for starch industry, due to its composition and large quantities produced. Cassava bagasse, is the waste generated in greater amounts, 1507 kg of cassava bagasse are produced per ton of processed cassava in wet basis. As for its chemical composition, dry cassava bagasse has 15% to 20% moisture content; 60% to 70% correspond to starch, and 12% to 14% to fiber[3]. However, fiber content may vary depending on the variety of cassava and technology used in starch extraction, resulting in higher or lower fiber values[4].

The addition of fiber of origin vegetable to products constitutes an alternative for the to obtain advantage of agro-industrial co-products such as cassava bagasse, which, thanks to its dietary fiber content, can give added value to food products[5]. Studies to incorporate raw materials of local origin in popular foods such as bread, pasta, among others have been reported. Pasta has a low glycemic index[6], which is beneficial for the health of diabetic people, it also has a high energy value, and other benefits that make it a very popular food among consumers and

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commonly used for the addition of nutrients. When of foods are added with fiber, sensory attributes and cooking properties can be affected in an undesirable way. Producing these enriched foods is a challenge between improving their nutritional value and preserving the organoleptic properties desired by the consumer[7].

In order to preserve the quality of enriched products, hydrocolloids are used due to their properties as gelling agents, emulsifiers, and fat substitutes, stabilizers to provide viscosity, improve firmness and give body to the final product, besides being useful to improve food sensory characteristics by modifying rheological properties[8,9]. Hydrocolloids in baking favor the machinability of dough, retain moisture and improve appearance; they are generally used in gluten-free formulations, being essential ingredients to obtain a structure similar to that provided by gluten[10]. Gluten network gives dough a unique functionality, which rheological behavior as a viscoelastic fluid makes it more extensible and elastic[11].

The addition of hydrocolloids with high water binding capacity to pasta helps control dough rheology, texture characteristics, and decreases cooking loss[12].

The objective of this study was to develop fiber-rich pasta by partially replacing wheat semolina with cassava bagasse and incorporation Carboxymethylcellulose (CMC) as structuring agent, obtaining a functional food to consumers.

2. Materials and Methods

2.1 Materials

Materials used to make the dough were; wheat semolina, Carboxymethylcellulose (CMC) and cassava bagasse obtained during the obtaining process of native starch.

Cassava bagasse was previously conditioned before being used in the preparation of pasta. A 10PSI press was made to decrease water content, followed by a drying process until a humidity of 11%. To finish with the process the grinding and sieving process to obtain uniformity in the final product[4].

Pasta was prepared according to the following elaboration process: mixing ingredients; wheat semolina, cassava bagasse and salt (1% flour-based) for 5 min; dissolution of CMC in water until achieving a uniform distribution[8], mixing and kneading ingredients in the fettuccine type pasta extruder machine, and drying until a final moisture between 10 and 11.5%.

2.2 Methods

2.2.1 Viscoelastic Properties of Dough

Viscoelastic properties of each sample were analyzed using a Modular Compact Rheometer MCR 302, connected to the Anton PaarRheoCompass1.12 software. Parallel-plate geometry with diameter of 25mm with a separation of 1mm was used. The sample was placed in the equipment leaving it to rest for 15 minutes. Linear viscoelastic region (LVR) was determined by performing an amplitude sweep in a range of deformation between 0.01-100% and frequency of 1.0 Hz. Frequency sweep test was performed varying the frequency of 0.01- 10Hz to determine storage modulus (G') (elastic property) and loss modulus (G") (viscous property). Data were adjusted to power law model (Equation 1 and 2. Then, tang delta tan () was determined (Ec. 3)[8].

$$G' = K'(\omega)^{n'} \tag{1}$$

$$G'' = K''(\omega)^{n''} \tag{2}$$

$$\tan(\delta) = \frac{G''}{G'} \tag{3}$$

3. Sensory Analysis

Sensory Analysis was performed using an acceptance test with a mixed structured 9-point hedonic scale. Texture (firmness and elasticity), color, taste and overall acceptability attributes of the product were evaluated, with help of a panel of 50 habitual consumers of pasta tasters. Finally, the most accepted pasta was selected for its subsequent sensory evaluation versus a traditional commercial fetuccini.

Pasta was previously hydrated in hot water taking into account the ratio one liter of water per 100 g of pasta during the optimal cooking time, that is, total cooking to the interior of pasta. Samples were drained from boiling water and immersed immediately in water at a temperature of approximately 25° C. Then they were placed under heat conditions before being served to tasters without addition additives[13]. The experimental design for sensory analysis was carried out by a completely random block design (DBCA), where tasters constitute the blocking factor. ANOVA at 5% significance and Tukey test was applied to the results.

4. Bromatological Characterization

It was made according to official AOAC standards, 2012[14] for moisture content, ash, protein, carbohydrates, total fiber and fat. This characterization was made for pasta presenting a higher sensory evaluation.

5. Statistical Analysis

Data obtained were analyzed by a completely randomized design (DCA) with two factors: of incorporation of cassava bagasse (10, 20 and 30%), and inclution of Carboxymethylcellulose (CMC) (0.5, 1, and 1.5%), using R 3.2.1 software. An analysis of variance (ANOVA) was performed at a level of significance of 5% and Tukey test for comparison of means.

6. Results and Discussion

6.1 Dough Rheology

Results of dynamic rheological tests are shown through the modulus of elastic (G') and viscous modulus (G") as a function of the oscillation frequency, as evidenced in Figure 1. It is notable that the elastic modulus (G') was greater than the viscous module (G") over the entire frequency range studied, showing that elastic properties dominated over viscose properties, defining dough as an consistent elastic gel[9]. This behavior is typical in products containing gluten, which contributes to the creation of networks in the matrix and to the good consistency of the mass. A similar behavior was observed in gluten-free pasta[15], bread made with microalgae[16], pastas added with dried blackcurrant pulp[17] and pastas added with cassava bagasse and xanthan gum[18], finding a predominant elastic behavior.

The increase in the content of cassava bagasse caused an upward predisposition in the value of the modules, corresponding to the increase in viscoelastic constants, which shows a stronger structure[19]. This can be attributed to the use of raw ingredients with high fiber content, with high fiber content on water absorption[16]. This ability is determined mainly by the presence of a large number of hydroxyl groups in fiber structure which interact with water through hydrogen bonds[20], and therefore increase dough rigidity or act as filler in the viscoelastic matrix[17]. In addition, it was observed that the increase in CMC content increased both modules, which may be related to

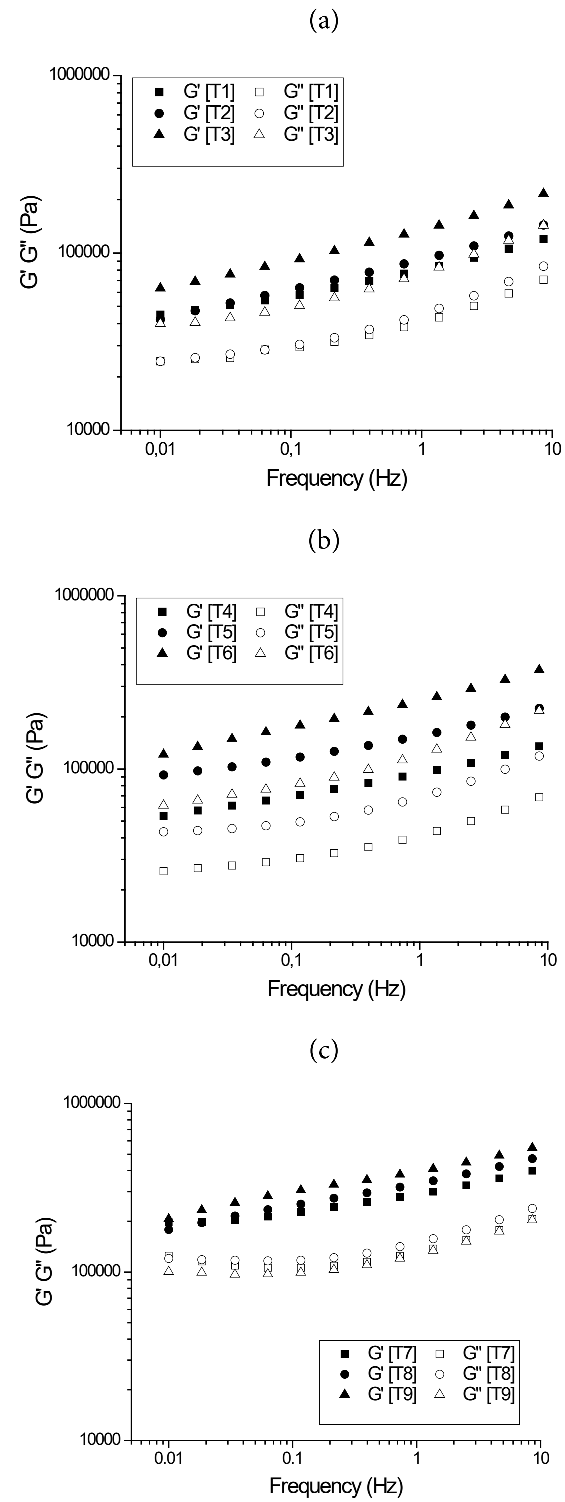

Figure 1. Viscoelastic behavior of dough for pasta with cassava bagasse in inclusions of (a) 10%, (b) 20% and (c) 30% and supplemented with Carboxymethylcellulose (CMC) in concentrations of: (■, □) 0.5%, (●, ○) 1% and (▲, Δ) 1.5%. (Full symbols (G'); open symbols (G").

the ability of hydrocolloids to copy viscoelastic properties of gluten found in semolina[21]. There is a three-dimensional network in dough where carbohydrate molecules and proteins that trap starch granules interact; there, hydrocolloids like CMC have the ability to help form a cohesive network. Similar results were reported in gluten-free pasta added with xanthan gum and locust gum[15], and in rice flour dough added with xanthan gum, obtaining stronger gels thanks to the thickener capacity of this hydrocolloid[19].

Tables 1 and 2 show viscoelastic parameters (K', n', K" and n"). It is observed that an increase in the amount of cassava bagasse causes higher values for K' and K" in all CMC concentrations evaluated. This behavior is possibly due to the strengthening of dough structure thanks to the reinforcement of viscoelastic proteins network with particles of the new raw material evenly distributed within the gluten matrix. Similar results were reported by[16] in dough added with microalgae up to a concentration of 3% and by[17] in dough added with dried blackcurrant pulp.

An increase in *K'* and *K"* values was found by increasing the CMC content in the dough formulation. This behavior can be due to the stabilizing and thickener properties of hydrocolloids. Research suggests that hydrocolloids interfere in the formation of gluten bonds, affecting both moduli differently, highlighting that gluten proteins

Table 1. Rheological parameters K' and K" of dough with cassava bagasse and added with CMC

	Cassava bagasse(%)		
CMC (%)	**10**	**20**	**30**
	K'		
0,5	81653,2±6402,2^{bB}	95817,8±9801,9^{cB}	294805,0±6932,9^{cA}
1	93218,1±4887,1^{bC}	158225,9±7967,4^{bB}	338856,6±2995,1^{bA}
1,5	137243,1±8091,7^{aC}	251778,9±23928,6^{aB}	449126,2±19934,2^{aA}
	K"		
0,5	42429,0±1277,6^{bB}	42943,5±2886,3^{cB}	137447,0±10589,1^{bA}
1	46859,1±3218,5^{bC}	71509,7±5044,1^{bB}	155968,4±4637,9^{aA}
1,5	79447,1±3756,1^{aB}	124759,2±14253,1^{aA}	132627,4±22536,7^{bA}

Means with different letters in columns (lowercase) and rows (uppercase) indicate a statistically significant difference according to Tukey test ($p < 0.05$).

Table 2. Rheological parameters n' and n" of dough with cassava bagasse and added with CMC

	Cassava bagasse(%)		
CMC (%)	**10**	**20**	**30**
	n'		
0,5	0,180±0,00^{bA}	0,160±0,00^{bB}	0,143±0,002^{aC}
1	0,203±0,003^{aA}	0,163±0,00^{bB}	0,154±0,006^{aB}
1,5	0,212±0,002^{aA}	0,185±0,00^{aB}	0,111±0,032^{bC}
	n"		
0,5	0,24±0,007^{bA}	0,221±0,006^{cB}	0,193±0,003^{aC}
1	0,277±0,005^{aA}	0,239±0,004^{bB}	0,197±0,005^{aC}
1,5	0,277±0,005^{aA}	0,263±0,000^{aB}	0,20±0,002^{aC}

Means with different letters in columns (lowercase) and rows (uppercase) indicate a statistically significant difference according to Tukey test ($p < 0.05$).

(glutenins) have been associated with elastic behavior, and gliadins with viscous behavior[22,23]. Similar results were found in gluten-free dough added with hydrocolloids[24].

The values obtained for n' and n" were different from zero, so can define dough rheological behavior as weak gels. Similar results were reported by[17] in dough added with dried blackcurrant pulp. The highest values for n' and n" were observed at the highest concentration of CMC, observing the effect of the hydrocolloid used in dough only after 1.5%. A similar behavior was reported in dough made with rice, observing that the incorporation of b-glucan did not show results at low concentrations[25].

The behavior of Tan (δ) of the dough as a function of frequency is evidence in Figure 2. Tan (δ) reveals of the solid-liquid balance of a viscoelastic material; 0° represents an ideal elastic solid and 90° an ideal viscous liquid. Therefore, for values of Tan (δ)<1 (G"<G') a behavior similar to the solid is observed, while Tan (δ)>1 (G">G') a behavior similar to the liquid is observed[26]. In the present study values for Tan (δ) less than 1 was obtained, evidencing the behavior of dough as a viscoelastic gel, mainly similar to the solid. This may be due to semolina proteins linked together by disulfide bonds, hydrogen and hydrophobic bonds to create a matrix[27]. Similar behavior was found in dough made with different varieties of wheat[28]. Likewise, it was found the values of Tan (δ) decrease at low frequencies (<1.0 Hz) and then increase, which indicates mobility within the gluten network chain.

Table 3 shows results of Tan (δ) less than 1. Taking into account that low values of Tan (δ), indicate a structure in the most elastic dough[28]. In dough made with 10% cassava bagasse the highest values were found for Tan (δ). This behavior coincides with values found in modules for dough prepared with the lowest content of cassava bagasse (10%), where a minor loss of integrity of gluten network is presented, so its structure is affected to a lesser extent by the presence of fiber. Gluten network loss of structure is due to the dilution of wheat gluten by proteins and fiber of raw material used to replace semolina[16]. This type of substitution by fibrous materials generates changes on dough rheology[29].

When using CMC at the highest concentration studied, the highest values were found for Tan (δ), which favors the increase in gel strength, caused probably because the hydrocolloids improve the ratio between starch granules[19]. The type and amount of hydrocolloid added in the formulation to dough generates changes

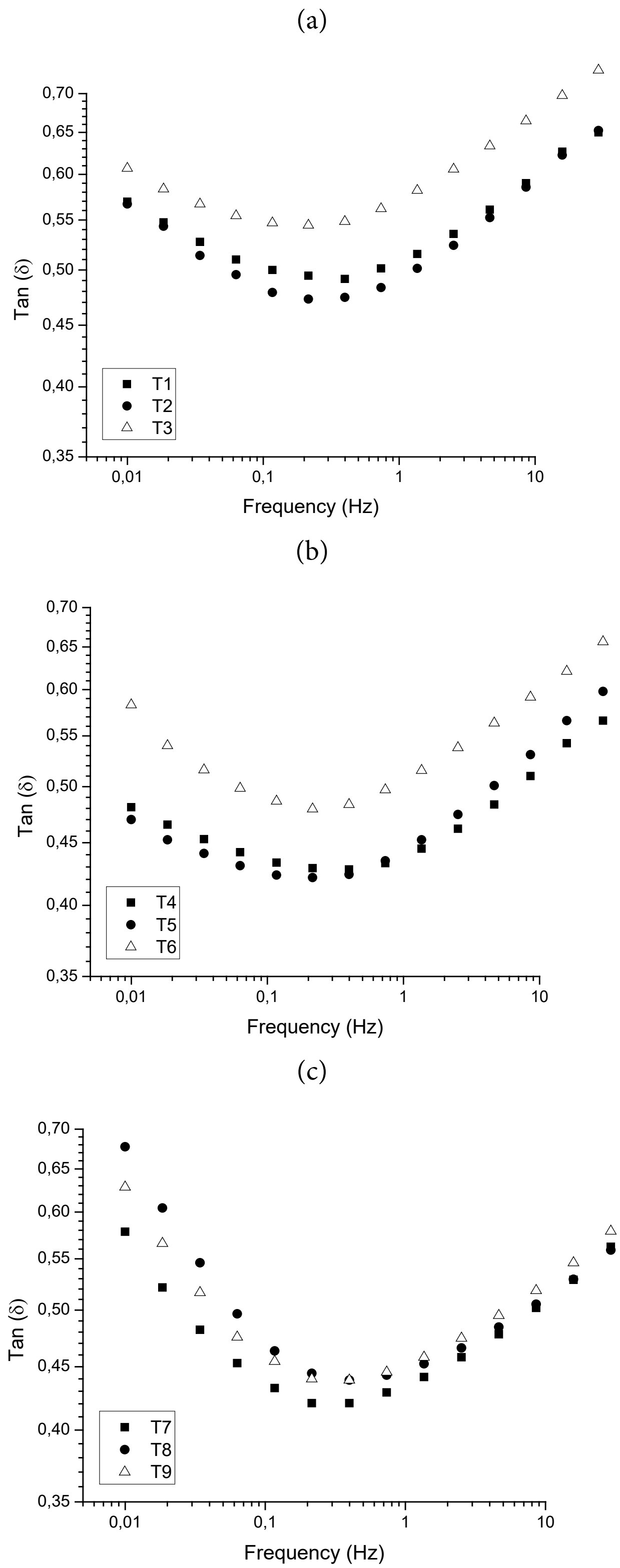

Figure 2. Behavior of Tan (δ) of dough with cassava bagasse in inclusions of (a) 10%, (b) 20% and (c) 30% and added with Carboxymethylcellulose (CMC) in concentrations of 0.5%, 1% and 1.5%.

Table 3. Tan (δ) of dough with cassava bagasse and added with CMC

	Cassava bagasse(%)		
CMC (%)	**10**	**20**	**30**
0,5	0,5±0,026^{bA}	0,434±0,019^{bB}	0,433±0,002^{aB}
1	0,479±0,005^{bA}	0,424±0,021^{bB}	0,464±0,014^{aA}
1,5	0,547±0,01^{aA}	0,487±0,038^{aB}	0,455±0,004^{aB}

Means with different letters in columns (lowercase) and rows (uppercase) indicate a statistically significant difference according to Tukey test (p <0.05).

on Tan (δ), which is related with molecular structure and conformation of the polysaccharide chain[30]. Dough rheological behavior is affected by the network structure of the hydrocolloids and gluten proteins, caused by their competition for water and intermolecular interactions. Hydrocolloids have strong ability to form complexes with gluten proteins through both ionic and non-ionic interactions, affecting dough strength[23].

7. Sensory Evaluation

Table 4 shows results obtained for the acceptance of pasta, where it is evident that pasta made with 10% cassava bagasse and 0.5% CMC obtained the highest acceptance in the almost attributes evaluated.

The evaluated attributes of texture, firmness, and elasticity were qualified by the tasters as: firmness between hedonic terms "I dislike slightly" and "I like moderately", and elasticity between "I dislike slightly" and "I like it slightly". Studies carried out by Mora, 2012[31] found that the addition of CMC favored sensory attributes of texture in pasta added with quinoa.

For attributes of color, pasta made with 10% cassava bagasse and 1.5% CMC obtained the highest averages, being rated by consumers in the hedonic term "I like moderately". This is possibly due to the fact that there is lesscassava bagasse that affects characteristic yellow color and also to the presence of CMC which favored coloration.

On the other hand, attributes of flavor and general sensation of pasta were cataloged by consumers between hedonic terms "I dislike slightly" and "I like slightly". Similar results in terms of overall acceptability were reported by[13], obtaining scores of more than 6 when the addition of legume flours did not exceed 30%.

To complement the sensory analysis in Table 5, the results of a comparison between the prepared paste with 10% cassava bagasse and 0.5% CMC versus a paste sold on the market are shown. Finding that the latter is located in the hedonic term "I like slightly". However, tasters did not find significant differences ($p \geq 0.05$) between samples regarding color attribute, although the addition of cassava bagasse generates browning in pasta, which is more noticeable in those made with 30% cassava bagasse.

Lower elasticity found in pasta containing cassava bagasse compared with the commercial one is possibly related to difficulty in creating the gluten network in the dough due to the fiber[32].

Regarding the flavor attribute of pasta, it was observed that tasters preferred the commercial one. Similar results were reported by[33] for pasta including lyophilized tomato.

Regarding the overall acceptability attribute significant differences were found, obtaining commercial pasta

Table 4. Results of pasta sensory analysis

Amount of bran (%)	Amount of CMC (%)	Firmness	Elasticity	Color	Flavor	General Sensation
10	0,5	6,82a	6,16a	5,48bc	5,28a	6,00a
	1	4,78c	4,90bc	4,30de	4,34bc	5,04bcd
	1,5	4,60c	5,30ab	6,56a	5,36a	6,32a
20	0,5	4,82c	5,24b	5,90ab	5,28a	6,16a
	1	5,04bc	5,16b	5,28bc	5,54a	5,70ab
	1,5	4,72c	5,24b	4,84cd	5,18ab	5,12bc
30	0,5	4,62c	4,16c	4,14de	3,92c	4,14e
	1	4,72c	4,82bc	3,90e	3,78c	4,26de
	1,5	5,68b	5,52ab	3,44e	4,96ab	4,72cde

Means with different letters in columns indicate significant differences ($p \leq 0.05$).

Table 5. Results of sensory analysis: processed pasta versus a commercial one

Pasta	Firmness	Elasticity	Color	Flavor	Overall Acceptability
10% cassava bagasse and 0.5% CMC	6.02a	5,78b	5.58a	5,26b	5,40b
Commercial	6,30a	6.28a	6.18a	5.98a	6.22a

Means with different letters in columns indicate significant differences ($p \leq 0.05$).

a greater acceptance. Similar results were found in pastas with addition of locust fiber[34], saffron powder[35] and legume flour[36], observing a decrease in general acceptability when increasing the quantity of new raw materials used.

8. Physicochemical Characterization of the Best Pasta

Physicochemical characterization of the best pasta made (10% cassava bagasse and 0.5% CMC) is shown in Table 6. There was an increase in fiber content of this pasta with respect to pasta made only of wheat semolina (0.42%), thanks to the addition of cassava bagasse which has a higher fiber content than semolina. A similar behavior was observed in pastas added with quinoa flour[37] and wheat bran, where fiber values between 4.9 and 13.9% were observed, showing this raw material as a great source of fiber[38]. Likewise[13] found an increase in protein and fiber content in pasta, thanks to the incorporation of legume flour, specifically from 77% to 275% in fiber, compared to pasta made of wheat only (0.92% of total fiber).

Differences in the composition of flours used to make pasta are also reflected in the nutritional profile of the final product. This was evidenced when comparing whole pasta with pasta added with flour rich in aleurone, where it was observed that processed pasta had twice the protein content and dietary fiber and less carbohydrate content than whole pasta[39].

Table 6. Physicochemical characteristics of pasta

Component	Quantity
Moisture	12.02%
Ashes	1.74%
Fat	0.13%
Protein	6.20%
Carbohydrates	79.91%
Total Fiber	13.89%
Soluble Fiber	2.37%
Insoluble Fiber	11.52%

Pasta added with cassava bagasse and CMC can be considered as a “fiber source” food, according to the European Commission’s 2006 food standards. However, the nutritional profile of pasta could be improved with the addition of other ingredients such as egg, oil and dehydrated vegetables.

9. Conclusion

All pasta dough made with cassava bagasse and CMC showed a behavior similar to an elastic gel, evidencing a storage modulus greater than loss modulus, with a slight dependence on frequency and Tan (δ) values less than 1. An increase in both moduli was found when increasing the amount of cassava bagasse in dough formulation, and thanks to the addition of CMC, the elastic behavior of dough was favored.

Sensory evaluation showed that tasters preferred pasta made with 10% cassava bagasse and 0.5% CMC with respect to the others. Highlighting firmness, elasticity, taste, and overall acceptability attributes. When comparing this pasta with a commercial one it was evident that the commercial one obtained better results, except for firmness and color where no statistical difference was evidenced.

The addition of cassava bagasse to pasta formulation improved its fiber content.

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