

Development and characterization of edible cups made from wheat, sorghum, and coffee pulp flour

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ABSTRACT

The use of plastic containers is increasing enormously, raising concerns about their improper disposal and their contribution to environmental pollution. The study aimed to develop and characterize edible cups made with wheat and sorghum flour, incorporating coffee pulp flour into their formulation. Percentages used of these flours in the three treatments studied were T1: 50-38-2 %; T2: 40-45-5 %; and T3: 30-52-8 %, respectively, and 10 % of cornstarch in all of them. Color, hardness, water absorption capacity, liquid resistance (distilled water at 20-25 and 75-80 °C), biodegradability, and fiber and protein analysis of the obtained containers were analyzed. Both one-way analysis of variance and the Tukey mean test were done at $p < 0.05$. The results, in comparison with a commercial edible cup, showed an acceptable cup color and a high protein (~11.8 %) and fiber (~3.62 %) content; hardness values (~37N for T1 and T2 and ~42N for T3) were lower. T2-T3 exhibited the low water absorption capacity and liquid resistance at 25°C (~28% at 30 min and ~165 min at 25°C, respectively), while T2 and T3 had the high-water stability at 80°C (~110 min). The developed edible cups exhibited the high biodegradability rate (~63%), decomposing in ~12 days. Including coffee pulp flour as an ingredient in the manufacture of edible cups allows obtaining containers with good structural integrity and physical properties superior to those of commercially available edible containers.

Key words: Comestible mugs; physical properties; biodegradable; coffee husk.

1 INTRODUCTION

The production of conventional disposable cups, made mainly from plastic and paper coated with chemicals, is increasing yearly (Simantiris, 2024). The mass production and disposal of plastic items, including disposable spoons and cups, has increased every year. In fact, between 4.8 and 12.7 million tons of plastic are dumped into the oceans annually (Habla et al., 2023; Nehra; Biswar; Roy, 2022). Improper disposal of these materials contributes to environmental pollution. Plastic cups are non-biodegradable materials, as they can remain in the environment for thousands of years without degrading, contributing to the accumulation of plastic waste in landfills, oceans, and other natural ecosystems. In addition, these cups can contain toxic additives, such as bisphenol A (BPA), which leach into food or beverages when the plastic comes into contact with them, especially if the cup is used for hot liquids, which is associated with health problems (Olea et al., 2023). It is, therefore, essential to look for sustainable alternatives, such as replacing these products with reusable, edible, and biodegradable cups made from starches, flours, and other natural ingredients (Hazra; Sontakke, 2023).

Edible cups made from wheat flour, egg, and butter are included in this trend. On the other hand, Sood and Deepshikha (2018) developed edible dishes from rice and sorghum flour and spinach extract, and Liu et al. (2020) succeeded in creating all-natural, biodegradable, water- and oil-resistant tableware using sugarcane and bamboo fibers. Similarly, cutlery made

from soy protein isolate, incorporating crude fiber extracted from bluebell stems, and edible spoons using sorghum, wheat, and rice flours and natural extracts to provide color and nutritional value are produced (Choeybundit et al., 2022; Sindhu; Swamy; Prashanthi, 2023).

Cereals such as sorghum (*Sorghum bicolor* L. Moench), of the grass family, which is noted for its high starch and fiber content (75-90% insoluble fiber and 10-25% soluble fiber) (Ananda et al., 2020), are used in packaging due to their hardness, as they provide better texture, promote durability and contribute to the nutritional value of edible containers such as ice cream cones (Kigozi et al., 2014). On the other hand, wheat, one of the most consumed cereals in the world, contains proteins such as gliadin and glutenin which, when mixed with water, form a gluten network that provides elasticity and tenacity to the dough, maintaining its shape in the oven and giving it structure and body (Rajendran et al., 2020).

In Peru and globally, coffee cultivation is a vital agricultural sector impacting both the economy and the environment (International Coffee Organization - ICO., 2023; Klingel et al., 2020). Different types of waste are generated during its processing, and coffee pulp is the main one. For every two tons of coffee produced, one ton corresponds to the pulp, representing 42 % of the dry weight of the coffee fruit (Arteaga et al., 2021). Despite being rich in fiber and high in protein, minerals (especially potassium), sugars, tannins, and caffeine (Gemechu, 2020), the pulp is often buried or dumped in rivers, contributing to and aggravating environmental

damage (Blumenthal et al., 2022). However, it can be used as an ingredient for manufacturing edible and biodegradable containers, and as Anand et al. (2024) mentioned, it could contribute to more sustainable coffee consumption.

In this sense, as an alternative to the use of plastic cups and to mitigate the associated problems with it and benefit from the by-products of the coffee industry, the present work aims to develop and characterize the physicochemical and structural properties and the biodegradability of edible cups made from wheat and sorghum flour, including coffee pulp flour (*Coffea arabica*) in its formulation.

2 MATERIAL AND METHODS

2.1 Materials

Coffee pulp of the organic Catimor variety was used to produce edible cups. This was purchased from the *Asociación Agrícola de Productores de Café de Altura* (Valle Tambopata) at San Juan del Oro, harvested in the province of Sandia, Puno, Peru, at an altitude between 1300 and 1800 m.a.s.l. (latitude 14°19'20"S and longitude 69°27'55" W). Sorghum flour was provided by the company Negocios del Agro EIRL, located in the city of Chiclayo (Lambayeque-Peru); wheat flour (Bell's®); corn starch (Duryea®); confectioners' sugar (Universal®); xanthan gum (Artstore®) and vegetable oil (Olyz Olivar®), were purchased in a local super market at Puno city. All materials were sent to the Laboratories of the Agroindustrial Engineering from Universidad Nacional del Altiplano de Puno (UNA-PUNO) and from Universidad Nacional de Juliaca, Peru.

2.2 Formulations used to produce edible cups

The coffee pulp was dehydrated in an industrial dryer (Boxa, LT102, Peru) at 50 °C for 6 hours. Subsequently, the dried pulp was ground in an electric grinder (Oster, ST-2886P, Peru). Table 1 presents the ingredients used to manufacture the edible cups, including the coffee pulp flour.

Table 1: Ingredients used for manufacturing the edible cups.

INGREDIENTS	TREATMENTS		
	T1	T2	T3
Wheat flour (%)	50	40	30
Sorghum flour (%)	38	45	52
Coffee pulp flour (%)	2	5	8
Corn starch (%)	10	10	10
Water (ml)	25	25	25
Confectioners' sugar (g)	18	18	18
Vegetable oil (ml)	12	12	12
Egg white (pcs)	1	1	1
Xanthan gum (g)	1	1	1

2.3 Production of edible cups

The edible cups were made following the methodology proposed by Mishra, Singh and Nanda (2024). All flours (wheat, sorghum, and coffee pulp) were sieved through a 354-micron mesh (W.S. Tyler, ASTM-E-11, USA) to obtain a fine and uniform mixture. Next, starch, confectioner's sugar, and xanthan gum were added. Subsequently, the wet ingredients, such as egg whites, vegetable oil, and water, were incorporated. The mixture was kneaded for 15 minutes using a dough mixer (Alston, HS10, Peru) until a firm, soft, and malleable dough was produced, making it easier to mold. In the molding process, the dough was laminated with a wooden rolling pin (Helferx, USA) to a thickness of 2 mm. The laminated dough was then placed in stainless steel cup-shaped molds and carved with a silicone spatula (Moacc, USA) to give it its final shape. The molds were then placed in an oven (Nova, Maxito 6B, Peru) at 180 °C for 30 minutes, which ensured the desired texture and baking. Once baked, the cups were allowed to cool at room temperature (18 °C) and then stored in airtight containers in a cool place until further analysis.

2.4 Methods of analysis

2.4.1 Color

The chromatic analysis of the cup samples was performed using a portable food colorimeter (MeterTo, LCD SC20, USA) to record the corresponding readings. Color densities were determined based on the CIE L* a* b* model, whose parameters provide the following information: L* indicates the lightness in a range from 0 (black) to 100 (white), while a* and b* represent the chromatic coordinates, where a* varies between green (-a) and red (+a), and b* between blue (-b) and yellow (+b).

2.4.2 Moisture

Moisture content was determined by the oven-drying method 925.10 (Association of Official Analytical Collaboration - AOAC, 2005). Two grams of the sample were placed in a previously weighed crucible and introduced in an oven at 110 °C for 3-4 hours. It was then cooled and weighed until the weight difference was constant. The moisture percentage was calculated with the following Equation 1:

$$\text{Moisture (\%)} = \frac{W_2 - W_3}{W_1 - W_2} \times 100 \quad (1)$$

Where:

W_1 is the weight of the Petri dish, W_2 is the weight of the Petri dish together with the sample, and W_3 is the weight of the Petri dish after drying.

2.4.3 Protein

It was carried out using the Kjeldahl method, which consists of digesting the organic matter with sulfuric acid in the presence of a catalyst, which makes the reaction product alkaline. The ammonia released is then distilled and titrated. The nitrogen content is calculated by multiplying the result by the conventional factor 6.25 to obtain the crude protein content and is calculated using the following Equation 2:

$$\text{Nitrogen (\%)} = \frac{(\text{Value of the sample title} - \text{Blank title}) \times \text{Normality of HCl} \times 14 \times 100}{\text{Sample weight} \times 1000} \quad (2)$$

$$\text{Protein content (g)} = \% \text{ Nitrogen} \times 6.25$$

2.4.4 Fiber

It was determined by method 962.09 (AOAC, 2005). Two grams of the dry sample were weighed into a beaker, and 5 ml of the 1.26 % dilution was added. H_2SO_4 was then added to the sample and heated under reflux for 15 minutes. The sample was filtered, and 5 ml of 1.26 % NaOH solution was added and heated under reflux for 15 minutes more. The mixture was filtered again, washed with ethanol, and heated under reflux for 15 minutes. Finally, the residue obtained, equivalent to the fiber content, was weighed Equation 3.

$$\text{Crude fiber (\%)} = \frac{(W_2 - W_1)}{(W_1)} \times 100 \quad (3)$$

Where: W_1 is the initial weight of the dry sample before chemical treatment, W_2 is the weight of the final residue obtained after all chemical treatments (acid, base, filtration, washing and drying).

Both protein and fiber analysis were done considering that they play an important role in the structural properties of cups.

2.4.5 Hardness

The hardness of edible cups was evaluated following the methodology by Rammya et al. (2024). A compression test on the edible cups was performed using a 10-mm-diameter cylindrical probe. The test was performed with a universal test texturometer (Instron Universal, model 3365, Norwood, Massachusetts, USA), configured with a 500 N load cell. The cup was measured at a speed of 2 mm/s. Each sample was subjected to compression testing to determine its rupture strength, and the analysis was performed in quintuplicate.

2.4.6 Water absorption

Water absorption capacity was performed according to Thagunna et al. (2023): samples were weighed and immersed in 150 ml of distilled water for periods of 10, 20, and 30 minutes. The amount of water absorbed was determined as the difference between the final and initial weight and expressed

as the mass of water absorbed versus the mass of the original sample. For each formulation, three trials were performed, and the results were calculated using the following Equation 4:

$$\text{Water absorption capacity} = \frac{W_{\text{final}} - W_{\text{initial}}}{W_{\text{initial}}} \times 100 \quad (4)$$

Where: W_{final} is the final weight of sample after water absorption and W_{initial} is the initial weight.

2.4.7 Resistance to liquids

Resistance to liquids was determined according to what was reported by Makarova and Ereemeeva (2021) and calculated as the time required for the edible cup to lose its integrity, measured in minutes. For the analysis, 90 ml of distilled water was poured into each edible cup, using two temperature ranges: between 20 and 25 °C and between 75 and 80 °C. The time elapsed until the container showed damage to its structure, evidenced by cracks forming due to contact with humidity, was monitored.

2.4.8 Biodegradability

For this test, edible cups were used as samples and buried in sterile, moist soil in the lands of the Isani community, Zepita, Puno (Perú), at a depth of 5 cm, to facilitate their complete degradation over time (Senthilkumar et al., 2024). The biodegradability rate along the time was calculated using the following Equation 5:

$$\text{Biodegradability rate (\%)} = \frac{W_{\text{final}} - W_{\text{initial}}}{W_{\text{initial}}} \times 100 \quad (5)$$

Where: W_{final} is the weight of sample at determined day and W_{initial} is the weight of sample at day 0.

2.4.9 Statistical analysis

The Completely Randomized Design (CRD) was used through an analysis of variance (ANOVA). In addition, Tukey's means tests were performed at a 5% significance level to identify important differences in the proportion of added flours concerning the physicochemical and structural properties of the edible cup. This analysis was performed using the free trial version of Minitab 19.1.0.1. Additionally, commercial edible cups of the brand "Cupffee" (Mirasloav Zapryanov, Bulgaria) were considered to establish a comparison sample.

3 RESULTS

3.1 Production of edible cups

Figure 1 shows the photographs of the edible cups obtained, both in front and plan view. A photograph of the Control edible cup is also included.

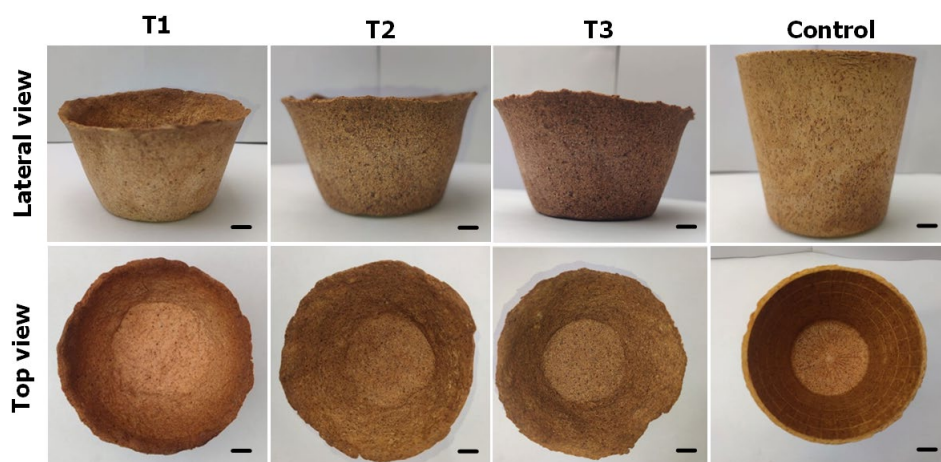


Figure 1: Edible cups made from wheat, sorghum and coffee pulp flours (T1: 50% wheat flour, 38% sorghum flour, and 2% coffee pulp flour; T2: 40% wheat flour, 45% sorghum flour, and 5% coffee pulp flour; T3: 30% wheat flour, 52% sorghum flour, and 8% coffee pulp flour). Control cup is “Cupffee ®” brand (Mirasloav Zapryanov, Bulgaria) that in its composition report oat bran, wheat flour, ascorbic acid, water, sugar, vegetable oil, stabilizers, sodium alginate, xanthan gum. Bar length = 1 cm.

The edible cups obtained have an inverted trapezoidal shape, with a base of 5.1 cm and a height of 5.3 cm. The base of the Control cup measures 5 cm and 7 cm in height.

3.3 Color

The average results and standard deviation of the color of the edible cups from the treatments and the Control cup are shown in Table 2 and illustrated in Figure 1.

The values obtained for the color of the edible cups showed significant differences between each treatment (T1, T2, T3) and the Control. The L^* values for T1 and Control were similar, ranging between 60.30 and 63.30, while in T2 and Control, significant differences were observed, with values between 45.63 and 63.30. The increase in the percentage of coffee pulp flour in treatments T2 and T3 reduced the L^* values, indicating greater darkness of these products.

As for the a^* values, the T1, T2, and T3 results present similar values, indicating a redder hue, with values between 6.07 and 6.86, while all treatments presented significant differences compared to the Control (11.36). This shows that the higher content of coffee pulp, together with the chemical and physical processes that occurred during drying, contributed to the products presenting a more pronounced red hue. On the other hand, the b^* values of the treatments and the Control showed a yellow tint, with statistically significant variations between treatments. The lowest values corresponded to treatments T3 and T2, with 18.40 and 19.63, respectively, indicating a more yellowish color.

3.4 Protein and Fiber

The results of the proximal analysis of the edible cups and the control sample are shown in Table 3. The moisture content in the control cup (6.15 %) and in treatment T1 (6.17

%) was significantly higher than in treatments T2 and T3 ($p < 0.05$). Regarding protein content, it was observed that all treatments exhibited significantly higher levels than the control. Likewise, all treatments had a higher crude fiber content (~3.62%) than the control (3.58%).

3.5 Hardness

Table 4 shows the hardness of the three edible cup treatments and the Control. Significant differences ($p < 0.05$) were observed between the edible cups T1, T2, T3, and the Control. The Control cup and T3 showed the highest hardness, with 54.36 N and 42.29 N, respectively.

3.6 Water absorption

The results of water absorption in edible cups are shown in Figure 2.

In the first 10 minutes, the edible cup had not absorbed a large percentage of water; by minute 20, the water absorption capacity of the cup increased until minute 30. After minute 30, all edible cups, including the Control cup, were observed to be swollen, thus unable to hold liquids adequately. The Control cup showed higher water absorption at 30 minutes, followed by T1, while the absorption percentage decreased in the other treatments. All cups absorbed between 27.14 % and 75 % water at room temperature. At 30 minutes, T1 had the highest absorption percentage. In contrast, treatments T2 and T3 showed the lowest absorption percentages (~28 %) after 30 min.

3.7 Resistance to liquids

Table 5 presents the results of the liquid resistance test using cold and hot distilled water. The edible cups of all treatments showed a resistance between 2 and 3 hours for cold water, while the resistance of the Control exceeded 3 hours with no leakage or

Table 2: Color assessment (CIE L*, a*, b*) on edible cups and the respective Control (C).

Treatments		L*	a*	b*
T1		60.30 ± 1.49 ^a	6.33 ± 0.75 ^b	22.83 ± 1.15 ^b
T2		45.63 ± 8.46 ^b	6.07 ± 0.23 ^b	19.63 ± 1.75 ^{bc}
T3		39.57 ± 2.52 ^b	6.86 ± 2.11 ^b	18.40 ± 1.01 ^c
Control		63.30 ± 4.12 ^a	11.36 ± 0.90 ^a	27.57 ± 2.11 ^a

T1: 50% wheat flour, 38% sorghum flour, and 2% coffee pulp flour; T2: 40% wheat flour, 45% sorghum flour, and 5% coffee pulp flour; T3: 30% wheat flour, 52% sorghum flour, and 8% coffee pulp flour. The values in superscript in each column indicate the significant difference ($p < 0.05$).

change in appearance observed. In hot water, edible cups from treatments T2 and T3 exhibited higher resistance (~110 min) than the Control (81 min) and T1 (30 min).

Table 3: Moisture, protein and fiber analysis of the edible cups and the commercial control cup.

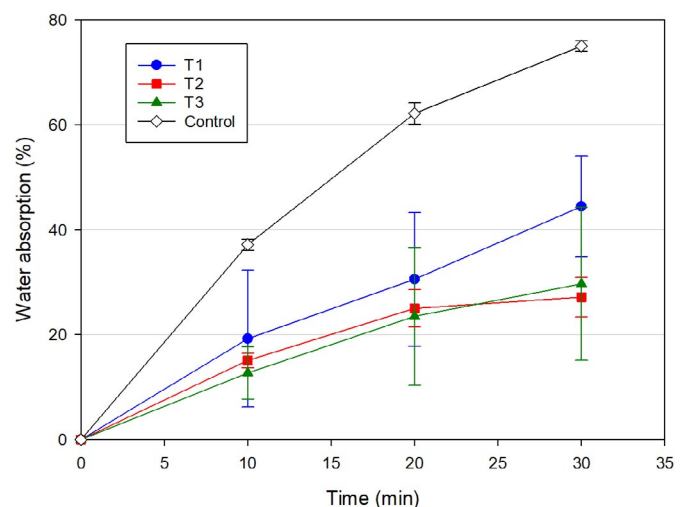
Treatments	Components for 100 g of sample		
	Moisture (%)	Protein (%)	Fiber (%)
T1	6.17 ± 0.75 ^a	11.58 ± 0.14 ^b	3.60 ± 0.20 ^a
T2	4.86 ± 0.09 ^b	11.78 ± 0.19 ^{ab}	3.56 ± 0.06 ^a
T3	5.86 ± 0.07 ^{ab}	12.21 ± 0.33 ^a	3.70 ± 0.11 ^a
Control	6.15 ± 0.21 ^a	11.36 ± 0.11 ^b	3.58 ± 0.12 ^a

T1: 50% wheat flour, 38% sorghum flour, and 2% coffee pulp flour; T2: 40% wheat flour, 45% sorghum flour, and 5% coffee pulp flour; T3: 30% wheat flour, 52% sorghum flour, and 8% coffee pulp flour.

Table 4: Hardness values of edible cups and the Control cup. Different letters in the same group are significantly different ($p < 0.05$).

Treatment	Hardness (N)
T1	35.41 ± 9.65 ^a
T2	39.29 ± 11.12 ^{ab}
T3	42.29 ± 11.99 ^{ab}
Control	54.36 ± 8.42 ^c

T1: 50% wheat flour, 38% sorghum flour, and 2% coffee pulp flour; T2: 40% wheat flour, 45% sorghum flour, and 5% coffee pulp flour; T3: 30% wheat flour, 52% sorghum flour, and 8% coffee pulp flour.

**Figure 2:** Graph of the variation of the percentage of water absorption according to the time of the edible cups of the three treatments studied and the Control sample.

3.8 Biodegradability

Figure 3 shows the results of the biodegradability rate variation of the edible cups after 12 days underground. There were not many differences between the biodegradability rate of the cups of the three treatments and the Control cup, with a range between 50 % and 68 % biodegradation during this period. A progressive biodegradation of the samples was observed on the third, seventh, and twelfth days.

Table 5: Results of resistance to liquid of the edible cups and the Control cup (C).

Treatments	Resistance to liquid	
	Stability (minutes)	
	Distilled water (20-25°C)	Distilled water (75-80°C)
T1	132	30
T2	170	104
T3	180	115
Control	195	81

T1: 50% wheat flour, 38% sorghum flour, and 2% coffee pulp flour; T2: 40% wheat flour, 45% sorghum flour, and 5% coffee pulp flour; T3: 30% wheat flour, 52% sorghum flour, and 8% coffee pulp flour.

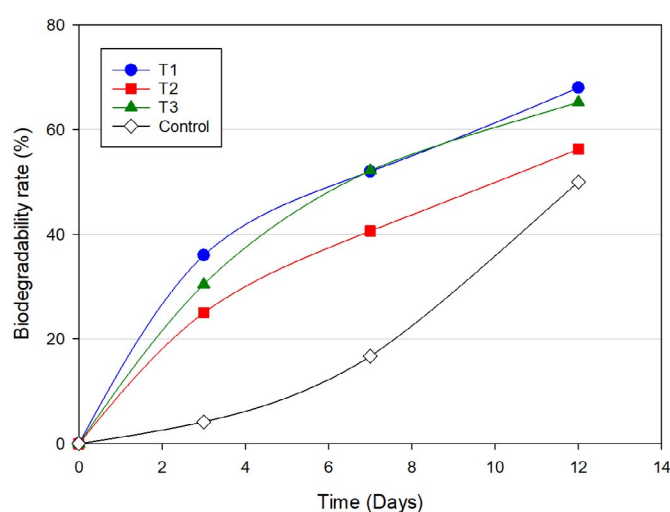


Figure 3: Biodegradability rate variation of edible cups and the control cup. T1: 50% wheat flour, 38% sorghum flour, and 2% coffee pulp flour; T2: 40% wheat flour, 45% sorghum flour, and 5% coffee pulp flour; T3: 30% wheat flour, 52% sorghum flour, and 8% coffee pulp flour.

4 DISCUSSION

4.1 Color

The incorporation of coffee pulp flour in edible cup formulations can increase the color intensity. A similar situation was observed when the percentage of coffee grounds was increased in processing edible cups. This may be because, during the drying process of coffee pulp, non-enzymatic browning contributes greatly to the color changes and significantly reduces the brightness (Torres-Valenzuela *et al.*, 2019).

4.2 Protein and fiber content

The higher protein content of the edible cups obtained, compared to the Control sample, could be due to the presence of coffee pulp flour in the formulations (Gil-Ramírez *et al.*, 2024). Similarly, incorporating a higher percentage of this

flour with sorghum flour in T3 would increase fiber content (Ananda *et al.*, 2020).

The protein and fiber content of all edible cups obtained was higher than that of dishes made with sorghum flour, rice, and spinach juice (Sood; Deepshikha, 2018). Similar is the case in the manufacturing of edible spoons with wheat flour and ragi ginseng powder (Hazra; Sontakke, 2023) and in that of edible spoons made with rice flour, millet, and wheat flour (Thagunna *et al.*, 2023). However, the amount of protein and fiber in the edible cups of the three treatments studied resembles that of edible dishes made with wheat flour, semolina, ragi, chickpea flour, orange peel powder, and mosambi (Stuti; Virginia, 2022).

4.3 Hardness

The edible cups were less hard than edible biodegradable spoons made from wheat, millet, and rice flour (Dordevic *et al.*, 2021; Yodkum; Pajareon; Yokesahachart, 2024). This fact could be attributed to the inclusion of coffee pulp flour and the progressive reduction of wheat flour in each formulation. At the same time, the increase in sorghum flour causes a slight increase in hardness (Sindhu; Swamy; Prashanthi, 2023) due to the higher amount of starch available in the formulation, as reported by Kigozi *et al.* (2016) in the manufacture of ice cream cones, where by increasing corn starch, mechanical hardness increased.

The degree of starch gelatinization and the availability of water during the baking of the containers are important factors in the hardness of the products (Tako *et al.*, 2014; Udachan; Sahoo; Hend, 2012). Edible tableware made from wheat and corn flour has higher hardness values than edible cups due to the lower amount of wheat flour used (Rammya *et al.*, 2024).

4.4 Water absorption

The reduced water absorption values are directly related to the quality of the edible containers (Wulandari *et al.*, 2023). The cups of treatments T2 and T3 present lower water absorption percentages than T1 and the Control cup. This is related to hardness values; lower water absorption percentages mean higher hardness values, as was also observed in the study by Siddiqui *et al.* (2023) on manufacturing edible spoons. The increase of sorghum flour together with coffee pulp flour may be the cause of the low water absorption percentages in treatments T2 and T3 and the probable formation of starch-water networks leading to water retention (Kabir; Hamidon, 2021; Thagunna *et al.*, 2023).

4.5 Resistance to liquids

Biodegradable edible cups do not let the liquid pass through since they do not crack or get wet when in contact with liquids until the beverage they can hold is finished. A hot beverage is consumed in an average of 20 to 30 minutes; however, in commercial establishments such as cafeterias, this duration could increase to one hour. According to Shulga *et al.*

(2023), the minimum acceptable duration of edible cups is 45 ± 5 minutes, which is attributed to coffee drinking habits.

The higher content of sorghum flour in the treatments likely contributes to the water resistance in comparison to the Control sample. The results obtained agree with those reported by Kabir and Hamidon (2021) on edible spoons used in hot water and with those reported by Kigozi et al. (2014) on sorghum cones, where permeability was higher when water content was low and sorghum flour concentration was high.

The edible cups obtained in the three treatments showed higher resistance than edible tableware made with applesauce and dried vegetables (Makarova; Ereemeeva, 2021); their durability increased when they were in contact with cold water and decreased when they contained hot water. The reduced resistance to hot water can weaken the bonds formed mainly with starch, making the cups brittle and susceptible to damage (Viswanathan; Pasupathy, 2017). Low temperatures help the containers last longer (Wulandari et al., 2023).

4.6 Biodegradability

During the observation period, the biodegradability rate of the edible cups increased due to the absorption of soil moisture. This fact may be attributed to the natural ingredients used in all samples without preservatives, suggesting that the addition of sorghum and coffee pulp does not significantly influence the degradation rate. The low rainfall during the development of the trial reduced biodegradability because the soil remained slightly moist. Higher moisture accelerates spoilage processes, which is consistent with that reported by Hazra and Sontakke (2023) in manufacturing edible spoons from moringa peel. A related study conducted by Sindhu, Swamy and Prashanthi (2023) found that edible spoons decomposed more quickly than edible cups. This difference could be attributed to the action of soil microorganisms and organic materials, which convert the spoons into carbon and energy through metabolic or enzymatic reactions.

5 CONCLUSIONS

Coffee pulp flour inclusion in the edible cup manufacture allows obtaining containers with structural integrity and acceptable color. Water absorption capacity, resistance to liquids, biodegradability rates, hardness, and protein and fiber content were superior to commercially edible containers. Coffee pulp improves the sorghum flour properties and reduces the wheat flour percentage in the edible container production, offering an innovative and environmentally friendly solution. Future works could consider introducing other flours, such as quinoa and cañihua, in the edible cup formulation.

6 AUTHORS' CONTRIBUTIONS

Conceptual Idea: Chipana, C.; Methodology design: Chipana, C.; Data collection: Chipana, C.; Data analysis and

interpretation: Chipana, C.; Leon, A. M.; Medina, W.; Writing and editing: Chipana, C.; Leon, A. M.; Medina, W.; Quispe, A. J.

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