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Full Length Research paper

Effect of the addition of cassava flour and beetroot juice on the quality of fettuccine

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The goal of the study was to investigate the effects of the addition of cassava (*Manihot esculenta* C.) flour, and beetroot juice on fettuccine quality. The proximate composition, physical and rheological parameters of semolina, cassava flour, and the blend (wheat: cassava) were evaluated. Also, the solid soluble content, titratable acidity and pH of the beetroot juice were evaluated. Additionally, the cooking time and solids losses, and microbiological enumerations of the fettuccine were analyzed. Finally, the fettuccine proximate composition and its sensorial acceptance were determined. Results showed that the protein content of the fettuccine lightly decreased with an increase in the blend of cassava flour, whereas it increased with the addition of beetroot juice. The cooking solids losses and the cooking time of the experimental fettuccine were similar to those of the control (100% wheat). The microbiological enumerations are in agreement with the requirements of the normative for pasta. The sensorial evaluation indicates that there was no significant difference between the fettuccines with respect to color, taste, texture and global appearance compared to the control (100% wheat semolina). Beetroot juice improves the diminution of protein content as a consequence of the substitution of wheat semolina with cassava flour. The fettuccine made with the blend showed similar quality and preference to the fettuccine made with semolina. Fettuccines with a good texture, physical properties, proximate composition and eating quality, and stable shelf life can be made with semolina, cassava flour and beetroot juice. These results could encourage the use of non conventional flours for development of food products.

Key words: Non-conventional flour, fettuccine, composite flour, cassava flour, *Manihot esculenta* flour, beetroot juice.

INTRODUCTION

Sweet and bitter varieties of cassava are grown in many tropical countries of Africa, Asia and Latin America. The use of cassava is usually for direct consumption or artesian products, and less is industrialized, consequently much is wasted (FAO 1989, Jadhav et al., 1990). The transformation of the cassava roots into flour could reduce storage losses, as well as, marketing and transportation costs. Since, the two cassava varieties are in transition from a starchy staple food to a raw material for food, feed and other industries (Pérez et al., 2007), including cassava in different food formulations. One of further studies are necessary to evaluate the feasibility of these could be the elaboration of “pasta or noodle” using cassava wheat composite flours. Indeed, is of consensus that pasta or noodle can be elaborated from sources different from wheat; for example, in the eastern part of the world, they can be manufactured with either starch or with the flour from root or tubers such as *Ipomoea batatas*, or a mixture of both. Noodles in various contents, formulations, and shapes have been the staple foods for many Asian countries since ancient time. The first noodles were made in China in about 4,000 AC using the foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum*

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miliaceum) flours (Lu et al., 2005). In fact, they can be made from wheat, rice, buckwheat, and starches derived from potato, sweet potato, and pulses (Fu, 2008). Noodle-based wheat are prepared mainly from 3 basic ingredients; flour, water, and salt.

Moreover, the traditional contemporary pasta of the Western World is made from simple ingredients namely, wheat flour (being the main conventional ingredient; wheat semolina), water, salt, and other optional ingredients. For example; one type of pasta is “fettuccine” (literally "little ribbons" in Italian), which is a flat, thick noodle, made of egg and semolina. Even if noodle is the term broadly used in research as previously used, by consensus the term "pasta" is used broadly and generically in order to describe a variety of noodles. Therefore, in this paper; pasta or fettuccine will be the terms used instead of noodle (Cambridge Advanced Learner's Dictionary, 2008).

Several studies are devoted to research the possibility of using non-conventional flour and starches in noodle preparation, including those of Charles et al. (2007), Inglett et al. (2005), Chen et al. (2002) and Suhendro et al. (2000) who are working with different sources. Usually these flours are quite low in protein content, then, a protein source must be added for enrichment. Some investigations have been focused in order to use protein isolate or flour from sources rich in proteins; such as, legumes or dairy products (Schoppet et al., 2006; Alireza and Bhagya, 2008; Petitot et al., 2009).

Beetroot juice is a simple way of making red-colored pasta, in order to improve its nutritional value and also to provide decorated food to the consumer. The beetroot juice is a rich source of boron, the mineral which plays an important role in the production of human sex hormones. Boron was used in the middles ages, as a treatment for a variety of conditions, especially illnesses relating to digestion and the blood (Nottingham, 2004).

The objectives of this study were to estimate the feasibility, at laboratory level, to elaborate with fettuccine and composite flour in a proportion 80:20 of wheat semolina: cassava flour using beetroot juice as humectants agent and also to evaluate the fettuccine proximate composition, functional properties and acceptability by consumers.

MATERIALS AND METHODS

Raw materials

Semolina

Commercial wheat semolina (WS), considered suitable for commercial pasta production was provided by the Pastificio America. C.A. from Caracas, Venezuela.

Cassava Flour

Cassava flour (CF) was prepared from sweet variety of cassava (*Manihot esculenta* Crantz.) tubers of the germoplam bank of FAGRO-UCV, by the procedure reported by Pérez et al. (2007).

Blend of semolina: cassava flour (80:20)

The blend of semolina: cassava flour (BSCF) was obtained mixing 80 part commercial wheat semolina with 20 parts of experimental cassava flour in a Kitchen-Aid Profesional_6 using number 2 for velocity for 10 min.

Beetroot juice

To obtain the beetroot juice (BJ), roots were selected, washed and hand peeled. The edible portion was cut into small pieces (2 inch cubes) and milled with potable water in a proportion of 1:1 (root: water), in a blender (Mertvisa mod: LQ4, 30129). The mixture obtained was passed through a muslin filter twice, and stored in sterilized glass bottles. The procedure was performed 1 day before the dough preparation in order to avoid losses of vitamins and color from the juice.

Fettuccine preparation procedure

The preparation of the fettuccine was performed using basic home procedures. WS and BSCF were transformed into dough, mixing it with water (for WS) or beetroot juice (for BSCF) in a proportion of 50 ml for 100 g of flour to obtain lumpy dough. The mixing procedure was performed using a Kitchen-Aid Profesional_6. The semolina: cassava flour and the adequate volume of water or beetroot juice were put in a Kitchen-aid bowl, and set-up with a stirring level of 2. The blend was mixed for 15 min, in order to develop the dough, and left for a rest period of 10 min. The dough was passed through the rollers of a home fettuccine machine (Extrusor Atlas, model 150mm-Deluxe, Italy); the fettuccine sheet was folded and passed through the sheeting rollers until it ensured homogeneity. The folding and sheeting were repeated twice. The dough sheet was left to rest for 15 min and then passed three times through the sheeting rollers at progressively decreasing roll gaps of 2.60, 2.33 and 2.00 mm. Immediately, after the last sheeting, the dough was passed through no. 12 cutting rollers and cut into strips about 30 cm in length × 0.6 cm wide × 0.2 cm gross. The strips were dried in a dehydrator Mitchell (Commenced Dryer, Manchester-England Mod. 6451/59) with a constant flow of hot air (45±2 °C, 75% RH) for 3 hours, then cooled and placed in a plastic bag for further tests.

Proximate composition and chemical and physicochemical characteristics

Fettuccine, cassava flour and semolina were analyzed in their proximate and chemical composition as follows: moisture, crude protein (N × 6.25), crude fat and ash contents were determined using the AACC (2003) method. Titratable acidity and pH were determined using the Venezuelan normative (COVENIN, 1994) procedure.

Beetroot juice properties

The beetroot juice was analyzed in soluble solid content with titratable acidity expressed as oxalic acid and pH by the COVENIN (1981) procedures.

Table 1. Proximate composition of the semolina, cassava flour and the semolina: cassava (80:20) blends*

Parameter (%)**	Semolina	Cassava flour	Semolina: cassava (80:20)
Moisture	12.85 ± 0.08[a]	13.79 ± 0.09[a]	12.65 ± 0.33[a]
Crude protein	12.01 ± 0.00[a]	0.96 ± 0.00[b]	9.00 ± 0.09[c]
Crude fat	1.67 ± 0.02[a]	0.64 ± 0.00[b]	1.41 ± 0.01[c]
Ash	1.00 ± 0.01[a]	1.90 ± 0.04[b]	1.32 ± 0.03[c]
Total carbohydrates	72.47[a]	82.71[b]	75.04[a]

*(dry basis). **Mean calculated from three different batches (n= 9). ***Dissimilar letters in the same row indicate statistical difference (p≤0.05). Total carbohydrates were calculated from the equation: Total carbohydrates = 100 - (moisture+ crude protein+ crude fat + ash contents).

Granulometric analysis

The particle size distribution of the semolina and blend was obtained using the U.S. Standard Sieve RO-TAP, 8", 110 V, 60 cycle with sieves of 40, 60, 80 and 120 meshes. 100 g of the sample were transferred carefully to the uppermost (coarsest) of a stacked series of graded sieves. The column was settled on the sieve shaking machine and then shaken for a period of 10 min. After that, each one of the fractions was weighed, and reported as a percentage.

Farinographic profiles

Farinographic properties of the semolina and the blend (semolina: cassava 80:20) were determined using a farinograph (Model: ohg Duisburg) follows the recommended procedures of AACC (2003). 50 g (14% moisture basis) of semolina or blend were mixed in a 50 g-mixing bowl with water by means of the farinograph burette, until the register mechanism (plot) reached 500 UB. The following parameters were calculated from the plot: arrival time, peak and departure time, stability and tolerance index (MTI) (Locken et al., 1977).

Hunter laboratory color coordinates

The color of the semolina, blend, beetroot juice and fettuccines was measured by the methodologies described in Hunter Laboratory Manual (2001) using a Hunter CIELAB (model 10, D- 65) equipped with a standard plate tile with the parameters L*= 94.64, a*= -1.24 and b*=2.27. The Hunter laboratory color coordinate system L*, a* and b* values were recorded as the means of three replicates.

Cooking analysis

Raw fettuccine (150 g) was cooked in 800 ml of boiling water until it reached the subjective textural point "*al dente*". "*Al dente*" refers to the desired texture of cooked pasta, in Italian Cuisine, and literally means "to the tooth". When the pasta is cooked "*al dente*", there should be a slight resistance in the center when the pasta is chewed. The time (in min) to reach this point was recorded (Feillet, 1984). Afterward, the fettuccine was rinsed with cold water. The cooking water was analyzed for solid content by evaporating the specific quantity of drained water and then weighing the remaining solids and losses were expressed as a percentage.

Microbiological test

A microbiological test for aerobic, and yeast and mold enumeration were performed by the pour-plate method described in BAM (1995). Plate count agar and potato dextrose agar/tartaric acid were used to plate count aerobic, and yeast and mold, respectively. In order to plate count *Escherichia,* the procedure of BAM (1995) was used while for *Staphylococcus aureus*, Baird-Parker agar Petri film plates were used with inoculation of 1 ml of 10^{-1} and 10^{-2} dilution, and incubated for 24 ± 2 h at 35 or at 37 ± 1°C (AFNOR, 2003).

Sensory analysis

Fettuccine samples were sensorial evaluated by a semi-trained panel by using a universally accepted hedonic scale analysis (Pedrero and Pangborn, 1989). The fettuccine was cooked in 800 ml of boiling water until it reached the textural point *al dente* (15 min) with samples randomly presented to 50 subjects of a sensorial group in order to evaluate their acceptance. A structured- hedonic scale of 7 points (1 = dislike very much to 7 = like very much) was used. Sample orders were randomized. For each, a portion of fettuccine with marinara sauce was given to the panelists at 60 ± 2°C (FAO, 2008). Six traits concerning sensorial evaluation (color, odor, flavor, texture and overall acceptance) were analyzed.

Statistical evaluation of analytical data

Analysis of variance (ANOVA) at the 5% level of significance was performed to obtain results from varieties, using the Statgraphics Program (Statistical Graphics Educational, version 6.0, Manugistics, Inc. and Statistical Graphics Corp., USA, 1992). When statistical differences were found, the Duncan's Multiple Range test was applied (p ≤ 0.05) in order to classify samples. Three replicates of all samples were used in the study.

RESULTS AND DISCUSION

Proximate composition of the flours

The proximate composition of the WS, CF and the BSCF blend is shown in Table 1. WS contains 12.01% crude protein, 1.67% crude fat, 1.00% ash. All of these parameters indicate the adequacy of this flour for noodle preparation (COVENIN, 2001). CF has higher contents of moisture (13.79%) and lower crude protein (0.96%) and crude fat (0.64%) than those of wheat semolina. On the other hand, composite flour has more intermediate values of crude protein (9.00%) crude fat (1.41%) and ash contents (1.32%) than the other two flours. Protein and ash

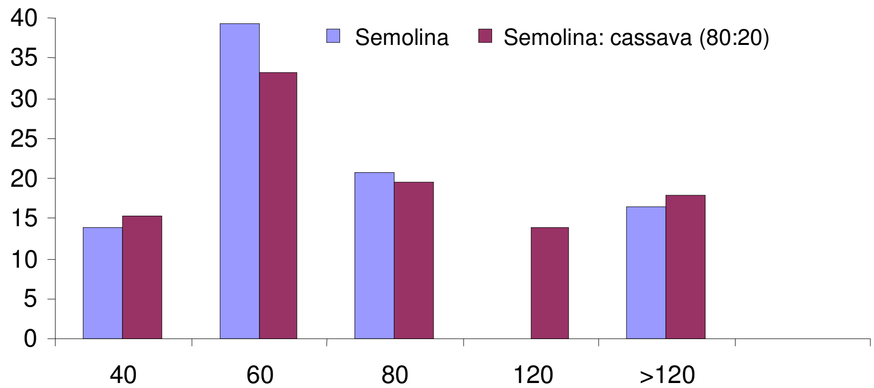


Figure 1. Granulometric analysis of semolina and cassava: semolina (80:20) flours (means of three replicates).

ash content and pasting characteristics are the key specifications in the study of flour uses. Pasta requires flour with high protein content (10.5 – 13.0%), because it gives it a firm bite and a springy texture (Hou and Kruk, 1998). Moreover, Venezuelan law requires a minimal protein content of 10.5 to 12.8% for durum or semi-durum semolina (COVENIN, 1982; 2001). Flour ash content, has been rated (Hou and Kruk, 1998) as one of the most important specifications, because it negatively affects pasta color. The flours with an ash content of 1.4% or less is considered an advantage because high ash con-tent of more than 1.4% could worsen the fettuccine color (Hou and Kruk, 1998). Most pasta flour requires an ash content of below 0.5%, but premium quality fettuccine is often made from flour containing 0.4% or less of ash content. COVENIN (1982, 2001) Norms, N°s 1946 and 217, requires 0.5 to 1.00% of ash content for durum or semi-durum semolina, respectively. The ash and crude protein content of the composite flour semolina: cassava could be questionable (Table 1), however, as will be demonstrated, this is possible to overcome by the addition of beetroot juice instead of water in order to develop the dough to elaborate the fettuccines.

Granulometric analysis

Granulometric analysis is becoming a more important quality feature than it was in the past, because modern pasta making technology has introduced new technical requirements in which semolina granular size plays an important role on the pasta quality. For example: vermicelli (a type of pasta) is elaborated using refined wheat flour (which has a granular size of 129 μ), or wheat semolina milled out of durum wheat (which has a granular size of 450 μ) (Vetrimani et al., 2005). When this vermicelli is elaborated by using durum wheat semolina with a granular size too big, it will not be hydrated enough during pasta making. Subsequently, it will produce a white spot on the vermicelli, which cannot be removed during drying. The white spot on the pasta is a reason to be rejected by consumers. Figure 1 is a representation of the particle sizes of WS and BSCF. As can be seen, there are no conspicuous differences between both samples; since they range between 40 (425 μ) to 80 mesh (125 μ). However, there is a slight decrease in the particle size of the BSCF to around 60 mesh (250 μ).

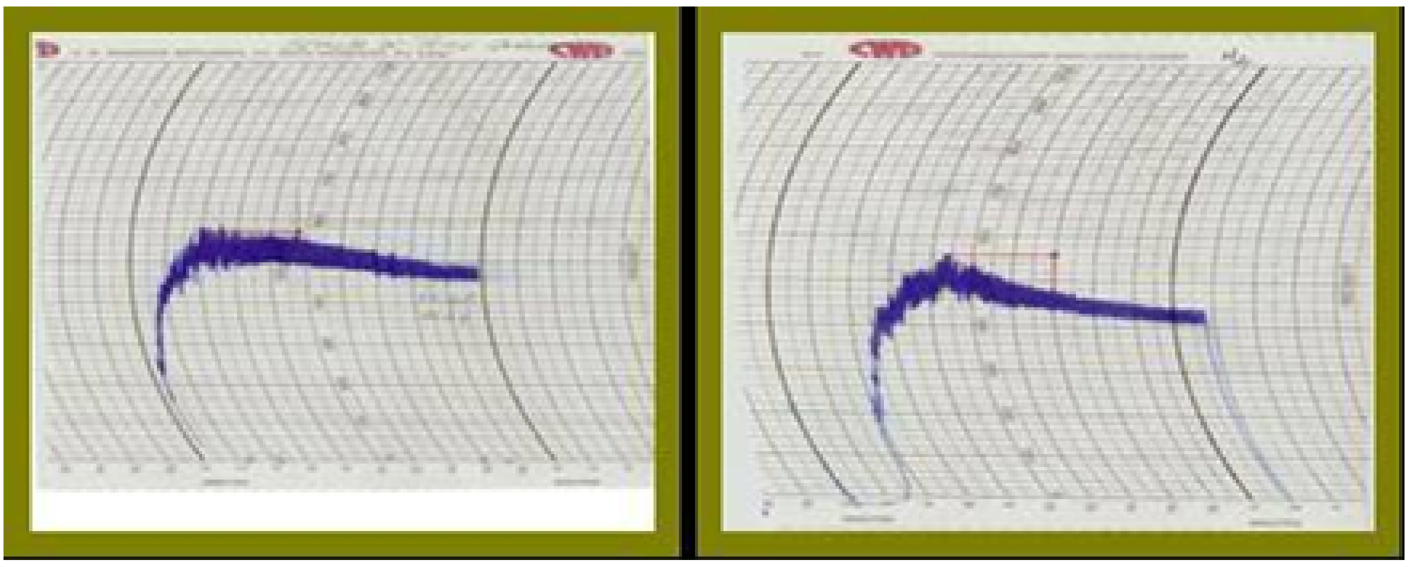
Farinographic profiles

Farinograph characteristics, as indicated in Table 2, show the profile of WS and BSCF. There are statistically significant differences ($p \leq 0.05$) among the parameters evaluated as can be noted in Table 2 and Figure 2. The absorption, departure time and stability values are higher in WS than those of BSCF. The absorption, or the amount of water required for dough to reach a definitive consistency (500 UB), is used to infer the amount of water for practical use. This study uses it to predict the amount of beetroot juice to use in the elaboration of the dough. As can be seen in Table 2, the 48.69% of absorption is indicative of the volume of beetroot juice that have to be added to the flour to reach a flour-beetroot dough with a uniform consistency, that can be easily handled and be molded to fettuccine. The high stability of WS as com-pared to BSCF points out the tolerance to mixing that this flour will have. However, this value should not have a not-able effect on fettuccine dough development. The departure time value also shows the strength of WF. WS shows a curve type II and the blend, a type III (Locken et al., 1977). It is quite an interesting information for product development research. Flours classified as dough with curve type II, yield short dough and consequently they have to be blended with other types of wheat. On the other hand, the majority of bakery flour are curve type III because they produce dough with appropriate elastic properties for good baking.

Table 2. Farinographic profile of semolina (WS) and the blend of semolina: cassava flour, 80:20 (BSCF).

Sample	WS	BSCF
Weight* (g)	49.65	48.69
Absorption (%)	55,6[a]	52[b]
Arrival time (min)	2,8[a]	5[b]
Peak time (min)	4,2[a]	7,8[b]
Departure time (min)	17,5[a]	10,8[b]
Tolerance index (MTI)	10[a]	100[b]
Stability (min)	14,7[a]	5,8[b]

*(14% moisture basis); **mean calculated from three different batches (n= 3); ***dissimilar letters in the same row indicate statistical difference (p ≤ 0.05).



WS: Curve type II, short peak time and long stability BSCF: Curve type III, medium peak time and short stability

Figure 2. Farinographic profile of semolina (WS) and the blend of semolina: cassava flour, 80:20 (BSCF).

Table 3. Beetroot properties.

Properties	Beetroot juice
Soluble solids (º Brix)	4
Titratable acidity (mg/100 ml as oxalic acid)	5.61
pH	6.34

Mean calculated from three different batches (n= 9).

Beetroot juice properties

Table 3 shows the solid soluble (°Brix) content, titratable acidity as oxalic acid and pH of the beetroot juice. It shows the low soluble solids content and the neutrality of the pH of the juice. Both facts are important for fettuccine quality. A neutral pH will not interfere with the taste and the low soluble solids content, should improve texture and avoid stain presence on the fettuccine. Beet stem and leaves are among the vegetables with an appreciable amount of oxalic acid (Kohman, 1939). Oxalic acid interferes with the absorption of calcium in foods because

Table 4. Color of semolina (WS) and semolina: cassava 80:20 (BSCF), beetroot juice (BJ) and the semolina fettuccine (FWS) and blend semolina: cassava 80:20 flour fettuccine (FBSCF).

				Fettuccine[2]	
Parameter[1]	**WS***	**BSCF***	**BJ***	**FWS**	**FBSC**
L*	86.51	89.39	0.51	87.66^{a}	61.56^{b}
a*	1.81	1.12	2.36	1.39^{a}	23.47^{b}
b*	27.74	21.13	0.32	16.27^{a}	-2.74^{b}

[1]Means of three replicates calculated by the Hunter equipment. [2]Dissimilar letters in the same row indicate statistical difference (p≤0.05). For obvious reasons, only fettuccine was compared statistically.

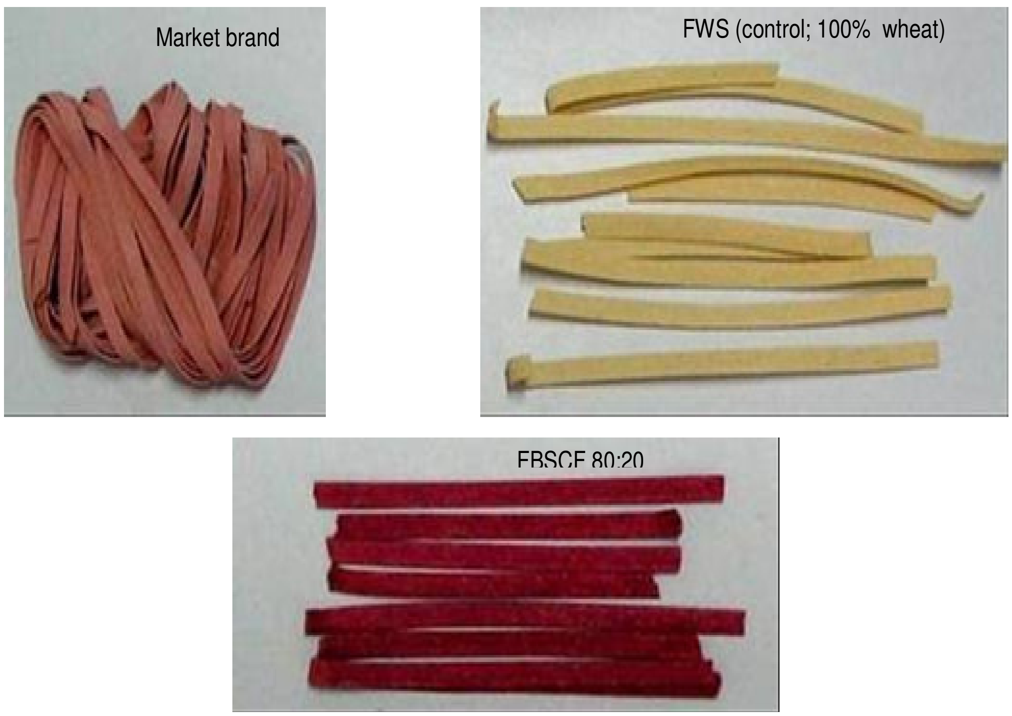


Figure 3. The effect of addition of beetroot juice (BJ) on the luminosity of FWS (fettucine), FBSCF (fettucine blend) and market brand.

foods because they bind with it, making it unusable by the body.

However, the amount that was found for beetroot juice in this study is half of what is reported for unpeeled beet, usually eaten. Therefore, it is presumed that there is no significant effect on the final amount of oxalic acid in the pasta, which will be a health concern.

Hunter laboratory color coordinates

Table 4 summarizes the parameters of color of WS, BSCF, BJ and fettuccine (FWS) and the fettuccine blend (FBSCF). Luminosity (L*) was severely affected by the addition of BJ to the dough (Figure 3), thus reducing to about 30%, when compared to the value for FWS ($p \leq 0.05$). On the other hand, despite that BJ showed lower values of a* (2.36) as compared with those of the fettuccine (FBSCF), the red hue dramatically increased (a*= 23.47) as expected, and the yellow decreased to reach a slightly green chroma (b*= -2.74). FWS has a higher L* and b* than FBSCF, which can be corroborated in Figure 3. Indeed, the beetroot's characteristic red color is most evident in FBSCF than in market brand fettuccine.

Proximate composition and some characteristic of the pasta

As can be seen in Table 5, the protein contents of FBSCF (11.11%) is in accordance with the Venezuelan

Table 5. Proximate composition, acidity, pH and cooking parameters of the wheat semolina fettuccine (FWS) and blend semolina: cassava flour fettuccine (FBSCF).

Parameter	Fettuccines	
	FWS (Control)	FBSCF
Moisture content (%)	12.64[a]	11.65[a]
Crude protein (%)	12.42[a]	11.11[b]
Crude fat (%)	1.68[a]	1.37[a]
Ash (%)	1.00[a]	1.00[a]
Titratable acidity as (% sulfuric acid)	0.06[a]	0.08[a]
pH	6.35[a]	6.43[a]
Cooking time (min)	15[a]	15[a]
Solids loss (%)	1,25[a]	1,28[a]

[1] Mean calculated from three different batches (n= 3). [2]Dissimilar letters in the same row indicate statistical difference ($p \leq 0.05$).

Table 6. Population of aerobic plate count (A. P. C), *E. coli*, S. aureus and yeast and molds of the fettuccines.

Microorganisms	FWS (control)	FBSCF
A. P. C. (CFU/ g)	1×10^3	1×10^3
E. coli (NMP/50 g)*	< 3,0 (**)	< 3,0 (**)
Yeast and mold (CFU/50 g)	<100	<100
S. aureus (cfu/50 g)	<10	<10

* Expressed as CFU: colonies forming units/g (n=5).

law requirements (10% minimum) (COVENIN, 1994), and it had no statistical difference with FWS (12.42%) used for control. When comparing the protein content of the pasta (Table 5) with those of the blend (Table 1), it has to be assumed that the increment of protein in pasta is due to the supply of beetroot juice. Even though the blends could be questionable (Table 1), the ash content of the pasta (Table 5) meets the Venezuelan law requirements (1.5% maximum) (COVENIN, 1994). The titratable acidity as a percentage of sulfuric acid also meets the Venezuelan law requirements (0.08% maximum) (COVENIN, 1994).

In regard to crude fat, the values reported in this study are in agreement with those reported by the Venezuelan Table of Food Composition (INN, 2001) for pastas (1.6 %).

The effect of the addition of cassava flour and beetroot juice on the cooking quality of pasta (fettuccine) is indicated in Table 5. The cooking time is especially important for the textural properties of pasta. Under cooked pasta is hard and gives a raw flour taste and unpleasant texture when chewed, while overcooked pasta is soft and soggy to handle and easily broken into small pieces. The cooking time to the point *al dente* was 15 min for both the control and the fettuccine made with the blend. On the other hand, the amount of residue in the cooking water is widely used as an indicator of cooked spaghetti quality. Lowest is the residue in the cooking water; highest is the pasta quality. There are quite low losses of solids in both kinds of fettuccines. Consequently, it can be established that the quality of FBSCF is quite similar to that of FWS.

Microbiological population of pastas

Mesophillic aerobic bacteriae are used as indicators of unsanitary practice. High viable counts often indicate contaminated raw materials, unsatisfactory sanitation, unsuitable time/temperature conditions during production or storage, or a combination of these (Thatcher and Clark, 1978). Dried desiccated or low-moisture (LM) foods are those that generally do not contain more than 25% moisture and have an a_w (activity of water) between 0.00 and 0.60. These are the traditional dried foods and they are shelf-stable foods (Jayaraman, 1988). As is shown in Table 6, the APC values are less than 10,000/g.

Molds and yeasts play an important role in food; some are desirable, but in dried foods such as flour and starches, they are undesirable, because they can produce toxins and become a significant public health risk. In this study, no significant population of molds and yeasts were detected as shown in Table 6. On the other hand, the population of *Escherichia coli and S. aureus* were

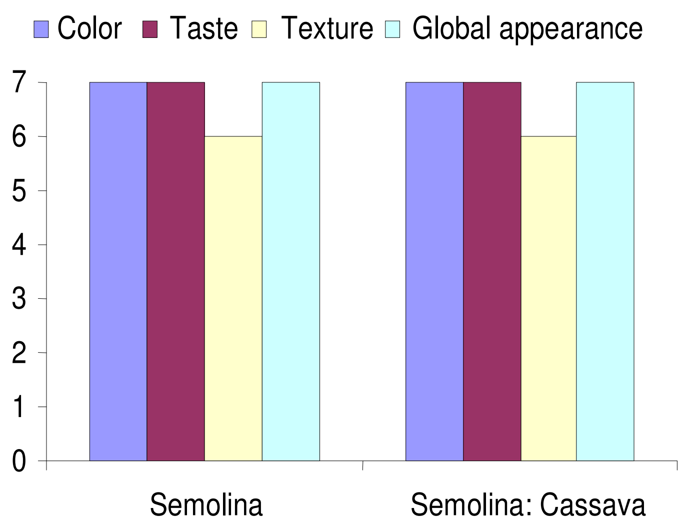


Figure 4. Sensorial evaluation of the fettuccines.

also quite low.

All of the microbiological accounts meet the requirements of the Venezuelan Norm 283-1994 (COVENIN, 1994) thus, we can expect that this pasta should have a stable shelf life and will not represent a public health risk.

Sensory analysis

Sensory evaluation of the cooked fettuccine (Figure 4) indicates no significant difference between the two fettuccines, FWS control and FBSCF, with respect to all parameters evaluated. Moreover, all the parameters were above the 3.5 line (acceptances mean values, when using the hedonic scale of 7 points).

Conclusion

Fettuccines with good texture and eating quality can be made using the composite wheat semolina and cassava flour in the 80:20 proportion respectively and moistening with beetroot juice. Despite the fact that protein decrease slightly with the addition of cassava flour, the fettuccine protein content was increased with the addition of beet-root juice. Fettuccine made with the blend showed similar quality and preference to that made with semolina. These results could encourage the use of non conventional flours for the development of food products.

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