Article

Baking and cookie quality of mixtures of whole amaranth flour and refined wheat flour

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Abstract

The imbalance between excessive intake and energy expenditure due to the consumption of refined carbohydrates and fats can be associated with overweight and obesity, causing a public health problem as currently happens in Mexico. Refined flour of bread wheat in the form of sweet bread and cookies are part of this intake. An alternative to this problem is the substitution in the making of these products for flour of whole grains, such as amaranth, for which the dough, as well as its baking and cookie quality must be characterized. Therefore, the objective of the present research was to evaluate the rheological characteristics of the dough, volume of bread and cookie factor of mixtures of whole amaranth flour and refined wheat flour. The whole amaranth flours were obtained from the lines called opaca and cristalina and the refined wheat flour from the varieties Fuertemayo F2016 and Urbina S2007. The mixtures with 5, 10 and 15% whole flour of opaca and cristalina amaranth decreased the strength and increased the tenacity of the dough, consequently they decreased the volume of bread and showed crumbs brown in color and with poor texture. On the other hand, mixtures with 25% whole flour of opaca and cristalina amaranth, as well as that of 75% whole flour of cristalina amaranth exceeded the cookie factor of the control variety 100% refined wheat flour, while the rest of the combinations were classified as very good for their cookie factor greater than 4.5. Based on the above, the substitution of whole amaranth flour does not decrease the cookie factor, so it is recommended to use it in mixtures with refined wheat flour, without detracting from the cookie yield, the opposite in the making of bread, where it decreased its volume and therefore the bread yield.

Keywords: baking quality, cookie quality, refined wheat flour, whole amaranth flour.

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Introduction

Based on the importance of its consumption in Mexico, bread wheat (*Triticum aestivum* L.) ranks second after corn, so it is considered a basic grain. Its main form of consumption is in the form of bread. The per capita consumption of bread is 33.5 kg, of which between 70% and 75% corresponds to white bread, and the remaining 30% and 25%, respectively, to sweet bread, cookies, and cakes, with refined wheat flour being the main raw material in the preparation of these products (CANIMOLT, 2016).

Based on the national survey of health and nutrition conducted in 2018, in our country, school-age children, of both sexes from 5 to 11 years old, showed 35.5% overweight or obesity; while the percentage of adults aged 20 years and over with overweight and obesity is 75.2 (39.1% overweight and 36.1% obesity), a percentage that was 71.3% in 2012 (Shamah-Levy *et al*., 2020), so Mexico is within the first three places with overweight or obese population and this problem is classified as one of public health (García-García *et al*., 2008).

According to Denova *et al*. (2010), one of the most frequent causes of overweight and obesity is the loss of balance between energy intake and expenditure due to the consumption of energy-rich foods (carbohydrates and fats), an additional fact is that more than 75% of the Mexican population does not know what their average daily calorie consumption should be.

Among these components that provide excess energy are sugary and soft drinks, given that the per capita consumption of a Mexican was 183 L (Olvera, 2022) and additionally, they consume products such as tortillas and bread made from refined flours of cereals such as corn and wheat. To help counteract the effects of this public health problem, one option is to reduce their consumption of these drinks and flours and increase the use of whole grains in the preparation of commonly consumed products, such as bread and cookies.

On the other hand, there are numerous studies where it is mentioned that amaranth grains (*Amaranthus* spp.) can be puffed, roasted and ground for use in bakery and biscuit products (Bhat *et al*., 2015), favoring alternative sources of protein with high nutritional value due to their concentration of albumins and globulins, and their better balance of essential amino acids such as lysine, methionine and threonine (Joshi *et al*., 2018). In addition, it can provide more calcium, magnesium, phosphorus, iron, potassium, vitamins, antioxidants, and fiber, compared to refined wheat flour.

On the other hand, due to the presence of antioxidant, anticancer, hypocholesterolemic, antidiabetic, anthelmintic and antidiarrheal compounds, the amaranth grain is recognized for its nutraceutical effect, that is, it has a favorable effect on consumer nutrition and health (Czerwin'ski *et al*., 2004; Huerta *et al*., 2012; Joshi *et al*., 2018). However, despite the above, in Mexico there is no interest in the crop, which is reflected in its low per capita consumption, which was 43 g for 2019 (SIAP, 2020). Popped amaranth in the form of 'alegría' is the most frequent form of consumption in Mexico. One option to increase its consumption is through diversification in product production (Ayala-Garay *et al*., 2020).

So, the incorporation of amaranth grain in the production of bakery and biscuit products can favor its consumption and its substitution for refined flours in the preparation of these products can be a healthy option for the consumer. Nevertheless, it is necessary to know the effect of incorporating wholegrain flours into mixtures and evaluate the quality of doughs, as well as their effect on baking and cookie quality. Therefore, the objective of the present research was to evaluate the rheological characteristics of the dough, volume of bread and cookie factor of mixtures of whole amaranth flour and refined wheat flour.

Materials and methods

Genetic material

The amaranth genotypes used were experimental lines called opaca and cristalina (*Amaranthus hypochondriacus*), which were provided by the amaranth improvement program of CEVAMEX-INIFAP. The bread wheat varieties Fuertemayo F2016 and Urbina S2007 were used to make bread and cookies, respectively, both varieties were provided by the wheat improvement program of CEVAMEX-INIFAP and released for irrigation conditions. Fuertemayo F2016 is characterized by presenting average values of pearling index of 48%, so it was classified as semi-hard grain, for the strength of its dough of 350 x 10^{-4} J it was classified as strong, while for its tenacity-extensibility ratio, PL= 1.1, it was classified as balanced.

So, the Fuertemayo F2016 variety is suitable for the mechanized bakery industry and can be used to improve mixtures with weak dough flours. On the other hand, the Urbina S2017 variety was classified as soft grain for its pearling index close to 60% and for its W less than 200 x10^{-4} J and its PL less than 1 is considered as weak-extensible dough, so it is suitable for making cookies and can also be used as an improver of wheats with strong and tenacious gluten.

Obtaining flours and mixtures

The flours were obtained in the wheat quality laboratory of CEVAMEX-INIFAP. To obtain the whole flour of opaca (WFOA) and cristalina (WFCA) amaranth, the raw grain was ground in a UDY-type mill using a 0.5 mm mesh to obtain some flour with homogeneous particle size. To obtain the refined wheat flour (RWF), the milling was carried out in a Bhuler mill (Brabender OHG, Germany) according to method 26-31 of the AACC (2005). The grain was conditioned by adding water to the grain according to the hardness and initial moisture of the grain, left to stand for 24 h and subjected to grinding. The flour produced by the grinding was sifted in a 10xx mesh to obtain the refined flour.

The mixtures to analyze the baking quality were: 100% RWF, 5% WFCA/95% RWF, 10% WFCA/90% RWF, 15% WFCA/85% RWF, 5% WFOA/95% RWF, 10% WFOA/90% RWF and 15% WFOA/85% RWF. On the other hand, the mixtures to evaluate the cookie quality were: 100% RWF, 25% WFCA/75% RWF, 50% WFCA/50% RWF, 75% WFCA/25% RWF, 100% WFCA, 25% WFOA/75% RWF, 50% WFOA/50% RWF, 75% WFOA/25% RWF, 100% WFOA.

In the case of the mixtures used to make the bread, it was possible to determine alveograph variables due to their low percentages of whole amaranth flour. These alveograph variables were the strength (W), tenacity (P), extensibility (L) and the tenacity-extensibility ratio (PL) of the dough, which were calculated from the alveogram, which was obtained from 60 g of the flour mixture using Chopin's Alveograph (Tripette & Renaud, France) using the method 54-30A of the AACC (2005).

In the case of the mixtures for making the cookies, due to the high percentages of whole amaranth flour incorporated, it was not possible to determine the alveograph variables of the doughs and it was decided to determine mixograph variables. The mixograph variables measured were kneading time (min), kneading stability (min) and mixogram height (mm), which were estimated by the mixograph (National Manufacturing Co., Lincoln, NE) using the method 54-40A of the AACC (2005) in samples of 10 g of the mixture.

Baking quality was measured as volume of bread (ml) by the straight-dough method (method 10-09, AACC, 2005) from 100 g of the mixture and determined on a volutometer by displacement of rapeseed (*Brassica campestris* L.). Additionally, the weight of bread (g), color of the crumb and structure of the crumb were determined. The cookie quality estimated as a cookie factor was determined using the method 10-54 (AACC, 2005). The dough was laminated to 0.9 cm thick and molded with a diameter of 5.5 cm then baked for 25 min at 220 °C.

The cookie factor was determined using five cookies, homogeneous in terms of size and shape, the diameter of each one and its height were measured with a vernier. The cookie factor was calculated using the formula W/L where: W= sum of the averages of five diameters and L= height of the five cookies one above the other and the mixtures were classified based on: cookie factor, excellent= 5-6, very good= 4.5-4.9, good= 4-4.4, regular= 3.5-3.9 and not suitable <3.4. A triplicate analysis was performed for each mixture. With the measured variables, an analysis of variance was performed with the SAS statistical package and the Tukey test ≤0.05 was used to indicate the differences between the mixtures.

Results and discussion

Alveograph variables and baking quality

Table 1 shows the averages of the variables of strength, tenacity, extensibility, and tenacity-extensibility ratio of the dough. The strength of the dough ranged from 193.3 to 434.3 x 10^{-4} J. The highest value was shown by the sample of 100% refined wheat flour corresponding to the Fuertemayo F2016 variety, which was classified as strong dough for its value greater than 300 x 10^{-4} J; while the mixture with 15% whole flour of cristalina amaranth was associated with the lowest value, in this way, for its value less than 200 x 10^{-4} J, it was classified as a weak dough. The rest of the mixtures were classified as medium strong dough for their values between 200 and 300 x 10^{-4} J.

Based on the above, it is observed that, as the percentage of whole flour of cristalina or opaca amaranth increased, the strength of the dough decreased; nevertheless, it was observed that the decrease in strength was greater when whole flour of cristalina amaranth was added. This is consistent with Vásquez-Lara *et al*. (2016), who found that substituting quinoa flour by 2.5 to 10% in mixtures with wheat flour decreased the strength of the dough.

Table 1. Comparison of means of the viscoelastic variables of the dough of mixtures of refined wheat flour (RWF) and whole amaranth flour.

Mixture	W (10^{-4} J)	PL (0.1-7)	P (mm)	L (mm)
100% RWF	434.3 a	1.5 d	152 b	79 a
5% WFOA/95% RWF	277 b	1.4 d	103.6 d	72.6 a
5% WFCA/95% RWF	260 cb	2 d	107.3 dc	53.3 b
10% WFOA/90% RWF	233 cbd	3 cb	128 c	43 cb
10% WFCA/90% RWF	232.3 cbd	4.1 b	150.6 b	36 cd
15% WFOA/85% RWF	221.6 cd	6.2 a	176.6 a	26 d
15% WFCA/85% RWF	193.3 d	3.5 b	127.3 c	36.3 cd

WFOA and WFCA= whole flour of opaca and cristalina amaranth, respectively. W= strength of the dough; PL= tenacity-extensibility ratio; P= tenacity of the dough; L= extensibility of the dough. Means with different letters in the same column are significantly different.

On the other hand, based on their tenacity-extensibility ratio (PL), all doughs were classified as tenacious for their values greater than 1.2. However, the highest values for PL were shown by combinations with percentages of 10 and 15 of whole flour of cristalina and opaca amaranth, respectively, with the highest (PL= 6.2) being for the mixture with 15% whole flour of opaca amaranth, the increase in PL is due to the increase in its tenacity (P) and decrease in its extensibility (L), since this mixture had the highest and lowest values for these variables (Table 1). While the lowest values for the tenacity-extensibility ratio were for combinations with 5% amaranth and for 100% refined wheat flour, which is due to their higher extensibility values.

In the specific case of extensibility, a general decrease was observed for all mixtures compared to 100% refined wheat flour. Based on the above, mixtures with whole flour of cristalina and opaca amaranth decrease the extensibility and strength of the dough, which is due to the presence of proteins and amaranth bran that do not allow the formation of the gluten network, which interferes with the optimal development of the dough. This is consistent with what was indicated by Cotovanu and Mironeasa (2021), who found similar results when replacing refined wheat flour with whole amaranth flour with different particle sizes and percentages of addition from 5 to 20%.

Table 2 shows the averages of the variables of bread volume, bread weight, crumb color and crumb structure. The bread volume of the mixtures varied from 485 to 700 ml; the difference is graphically represented in Figure 1. The highest value corresponded to the 100% refined flour of the control variety, followed by the mixture with 5% whole amaranth flour, which was the one that less decreased the volume of bread, the above is consistent with Sanz-Penella *et al*. (2013), who indicated that the proportion of the substitution of whole flour of *Amaranthus cruentus* can be up to 20 g per 100 g of wheat flour to maintain the quality of the cookie and take advantage of the nutritional value of amaranth.

The lowest values corresponded to combinations with 15% whole flour of opaca and cristalina amaranth. Most mixtures with whole flour of opaca and cristalina amaranth showed values less than 600 ml, which is consistent with Ayo (2001), who reported a decrease in the baking index for percentages of substitution of up to 50% with amaranth flour. However, combinations with whole flour of opaca amaranth of 5 and 10% exceeded in volume the same percentages with whole flour of cristalina amaranth.

Table 2. Comparison of means of the baking quality variables of mixtures of refined wheat flour and whole amaranth flour.

Mixture	BV (ml)	BW (g)	CC	CS
100% RWF	700 a	159.3 b	9 b	7.5 a
5% WFOA/95% RWF	657.5 ba	157.6 b	7 c	7 ba
10% WFOA/90% RWF	590 bc	161.5 ba	6.5 dc	6 b
5% WFCA/95% RWF	542.5 dc	167.4 ba	7 a	7 ba
15% WFCA/85% RWF	510 d	167.7 ba	7 c	6 b
10% WFCA/90% RWF	501.6 d	170.3 a	7 c	6 b
15% WFOA/85% RWF	485 d	162 ba	6 d	6.5 ba

WFOA and WFCA= whole flour of opaca and cristalina amaranth, respectively. Means with different letters in the same column are significantly different. BV= bread volume; BW= bread weight; CC= crumb color (9= yellow-cream, 7= brown and 6= dark); CS= crumb structure (7= regular and 6= poor).

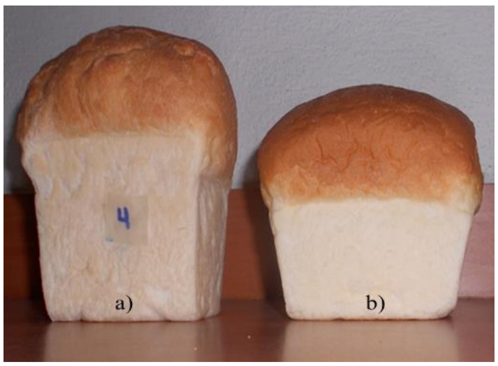

Figure 1. Graphic representations of bread volume of mixtures of refined wheat flour (RWF) and whole amaranth flour, a) 700 ml (100% RWF); and b) 485 ml (15% WFOA/85% RWF).

For the specific case of the mixture with the combination with 15% whole flour of opaca amaranth, it was associated with the lowest volume of bread, which is due to its higher value of tenacity (Table 1), which disfavors the volume of bread according to Nash *et al*. (2006), who indicated that the decrease in strength and extensibility, as well as the increase in tenacity decrease the volume of bread. On the other hand, Miranda-Ramos *et al*. (2019); Cotovanu and Mironeasa (2021) indicated that the presence of amaranth proteins hinders the gluten network and detract from the expression of bread volume. However, these authors also reported an increase in the concentration of protein, lipids, minerals, and fiber in bread products made with amaranth flour mixtures.

In general, the weight of bread increased as refined wheat flour was replaced with whole flour of opaca and cristalina amaranth. For the color of the crumb, the sample of 100% refined flour presented yellow-cream color, while for the rest of the mixtures, they presented brown and dark color. In the case of the crumb structure, it was regular for 100% refined wheat flour, as well as mixtures with 5% whole flour of opaca and cristalina amaranth, the rest of the combinations showed poor crumb structure (Table 2). The coloration and structure of the crumb was modified due to the presence of amaranth bran and flour, the above agrees with what was indicated by Álvarez-Jubete *et al*. (2010), who reported its darkening due to the presence of amaranth and quinoa flour. Likewise, Coțovanu and Mironeasa (2021) indicated that the crust of bread enriched with chia presented dark coloration. Figure 2 graphically presents the cream-yellow color of the crumb and the type of crumb found in some mixtures analyzed.

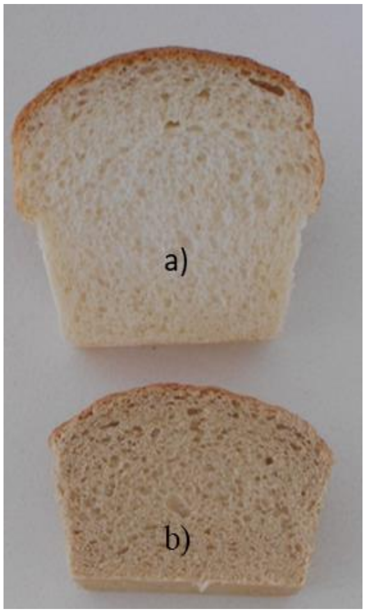

Figure 2. Graphic representation of the color and structure of the crumb, a) yellow-cream color and regular (100% RWF); and b) brown color and poor (15% WFOA/85% RWF).

Mixograph variables and cookie quality

Table 3 shows the averages for the kneading variables obtained from the mixogram of the different mixtures. Kneading times ranged from 1 to 3 min. The sample of 100% refined flour of the control variety Urbina S2007 presented a value of 1.6 min of kneading, characteristic of weak dough. In general, the substitution of refined flour for whole flour of cristalina amaranth decreased the kneading time. However, the sample with 100 and 75% whole flour of opaca amaranth increased the kneading time.

On the other hand, the height of the mixogram is associated with the concentration of protein in refined wheat flour, in such a way that the sample with the highest value corresponded to 100% refined flour and by decreasing its percentage of wheat flour in the different mixtures, it generally reduced the height of the mixogram. Osella *et al*. (2008) indicated that low strength values indicated by short kneading times favor cookie quality measured as cookie factor. This is corroborated by what was found in this study since mixtures 75 and 25% whole flour of cristalina amaranth with short kneading times were associated with high values of cookie factor, while the samples 100% and 75% opaca amaranth flour with longer kneading times showed the lowest cookie factors.

Table 3. Comparison of means of the kneading variables of mixtures of refined wheat flour (RWF) and whole amaranth flour.

Mixture	KT (min)	KNS (min)	MH (mm)
50% WFOA/50% RWF	1 cd	1.9 bc	34.3 c
75% WFCA/25% RWF	1 d	2.5 ba	35.5 bc
25% WFCA/75% RWF	1.1 cd	1.8 bc	35.3 bc
100% WFCA	1.1 cd	1.9 bc	39.3 bc
25% WFOA/75% RWF	1.3 cbd	2 bac	26.7 d
50% WFCA/50% RWF	1.3 cbd	1.5 bc	35.3 bc
100% RWF	1.6 cb	1.3 c	46 a
100% WFOA	1.8 b	1.9 bc	41.3 ba
75% WFOA/25% RWF	3 a	2.9 a	25.6 d

WFOA and WFCA= whole flour of opaca and cristalina amaranth, respectively. KT= kneading time; KNS= kneading stability; MH= mixogram height. Means with the same letter within columns are statistically equal.

Table 4 presents the averages of the variable of cookie factor, which varied from 4.5 to 5.8, in this way all mixtures were classified as very good to excellent based on their cookie factor. Figure 3 graphically represents the cookie factor. Most of the mixtures were classified as excellent for their value greater than 5, except for the combination with 75% whole flour of opaca amaranth and the sample of 100% whole flour of opaca amaranth, which were classified as very good for their values of 4.7 and 4.5, respectively.

Table 4. Comparison of means of the cookie quality variables of mixtures of refined wheat flour (RWF) and whole amaranth flour.

Mixture	Cookie factor
25% WFOA/75% RWF	5.8 a
75% WFCA/25% RWF	5.7 a
25% WFCA/75% RWF	5.5 ba
100% RWF	5.3 bac
50% WFCA/50% RWF	5.3 bac
50% WFOA/50% RWF	5 bdc
100% WFCA	5 bdc
75% WFOA/25% RWF	4.7 dc
100% WFOA	4.5 d

WFOA and WFCA= whole flour of opaca and cristalina amaranth, respectively. Means with the same letter within columns are statistically equal. Cookie factor (excellent= 5-6; very good= 4.5-4.9; good= 4-4.4; regular= 3.5-3.9 and not suitable <3.4.

It is important to indicate that these samples presented the highest values of kneading time, which is indicative that the strength increased and therefore the cookie factor decreased, which agrees with Duyvejonck *et al*. (2012), who reported that the greater strength of the dough is negatively related to the diameter of the cookie and consequently to the cookie factor. On the other hand, it was identified that the combinations with 25% whole flour of opaca and cristalina amaranth, as well as that of 75% whole flour of cristalina amaranth exceeded the rest of the combinations and the control variety in cookie quality. This contradicts what was indicated by Sindhuja *et al*. (2005), who reported a decrease in the cookie factor with substitution of 10 to 35% *Amaranthus gangeticus* flour.

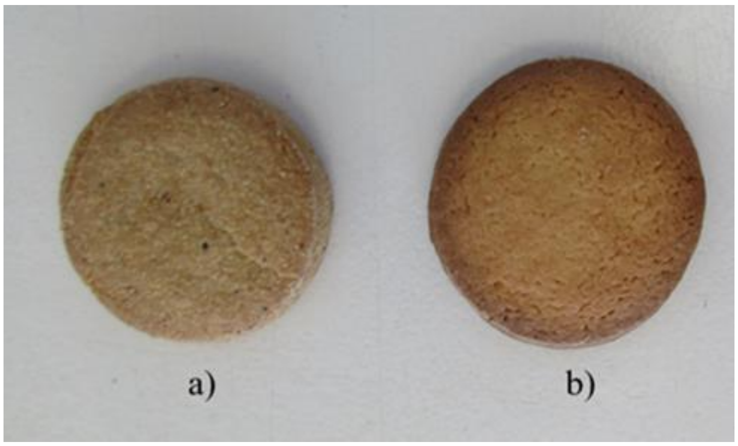

Figure 3. Graphic representations of the cookie factor of mixtures of refined wheat flour (RWF) and whole amaranth flour, a) 4.5 (100% WFOA); and b) 5.8 (25% WFOA/75% RWF).

However, this may be due to the different species of amaranth used in the preparation of cookies. On the other hand, Man *et al*. (2017) agrees with our results since they found that the incorporation of amaranth flour favored the cookie factor and increased the protein and fiber contents. Based on the above, the substitution of whole flour of opaca and cristalina amaranth in the production of cookies maintained the cookie factor and even improved it, which consequently maintains the cookie yield that is commercially reflected in the number of cookies per unit of flour used.

Conclusions

The substitution of whole flour of opaca or cristalina amaranth for refined wheat flour decreased the strength and extensibility and increased the tenacity of the dough, which disfavored the volume of bread, which was also associated with crumbs of poor structure and brown color. The substitution of 5 of whole flour of opaca amaranth affected to a lesser extent the baking quality measured as volume of bread. On the other hand, for cookie quality measured as cookie factor, all combinations were classified as very good to excellent.

Even combinations with 25% whole flour of cristalina and opaca amaranth, as well as 75% cristalina amaranth flour were identified with cookie values higher than the control sample of 100% refined wheat flour. So, it is important to indicate that the replacement of refined wheat flour with whole amaranth flour should be promoted in the baking and cookie market, which would promote its consumption and take advantage of its nutritional value.

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