Investigation note

Method to evaluate amaranth grain trapping

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Abstract

To define a procedure to evaluate amaranth grain expansion, three experiments were established. The first, to optimize the method of determination of humidity in grain in drying oven. The second to define the feasibility of modifying the moisture content to 12, 14 and 16%, due to the effect of water quantity and conditioning time. The third was to determine the volume of grain expansion by sample size (15 and 30 g) and humidity (10, 12, 14 and 16%). The treatment that worked best for the determination of grain moisture was 2 g of sample, 2 h of drying at 130 °C. It is possible to modify and adjust the grain moisture content by adding water. No effect on the moisture content was observed for the different conditioning times. The moisture content with which the highest trapping volume was obtained was 12 and 14%. There were no significant differences in the volume of grain trapping in samples of 15 and 30 g.

Keywords: conditioning, grain moisture, expansion volume.

Reception date: February 2018
Acceptance date: April 2018

Introduction

The trapping of the amaranth grain gives the grain better flavor, color, aroma and increases the quality of protein (Zapotoczny *et al*., 2006; Morales *et al.*, 2014). The grain is commonly burst with a fluidized bed system with hot air. In this system, the factors that affect the volume of trapping of the grain are mainly the moisture content of the grain, the temperature and the hot air flow rate (Lara and Ruales, 2002). Also, the volume of grain expansion in cereals affects the growing environment and the variety (Mishra *et al*., 2014). There is no common method for determining moisture in the amaranth grain.

In order to study the effect of the varieties and environment of the crop on the grain trapping, it is necessary to homogenize the operating conditions of the trap system due to the variation in the moisture content of the grain. Humidity that is a function of the place of production, handling and storage.

The objective of the present study was to define a procedure to evaluate amaranth accessions by volume of trapping, several recommendations of humidity determination by the stove method, efficiency of the addition of water in the modification of the moisture content of the seed were evaluated, the effect of conditioning time (addition of water) on the moisture content of the seed, the effect of moisture content of the grain on the burst volume and the effect of sample size on the evaluation of grain trapping volume . Three experiments were carried out from February to March 2015 in the facilities of the Postgraduate School Campus Puebla, in Cholula, Puebla, Mexico.

Experiment I. Determination of moisture in amaranth grain by effect of stove temperature, variety, sample weight and hours of drying in an oven.

Two improved varieties (VAR) ʽNutrisol’ and ʽLaura’ were used. Both harvested from batches of commercial production in 2014. Two sample weights (PMUES) of 2 and 5 g were handled. The samples were dried in a convection oven at two temperatures (TEMP), 103 and 130 °C. Three levels of drying time (TSEC) 1, 2, and 4 h were applied. The measured variable was moisture content of grain (CHUM) in percentage on dry basis. A completely randomized experimental design with a factorial arrangement with three replications was used. Each observation was made in duplicate.

Experiment II. Amaranth grain humidity due to conditioning effect due to mass balance and conditioning hours.

The study factors were initial grain moisture and conditioning time (TACOND). The humidity levels of 10, 12, 14 and 16% and TACOND of 4, 8, 12 and 24 h were used. The ʽLaura’ was used, with initial humidity of 10%. The CHUM was modified to 12, 14 and 16%, adding distilled water. To modify the desired or target humidity was calculated with the following mass balance formula:

$$A=\frac{(1-X1)\ S1}{1-X2}-S1$$

Where: S1= dry weight of unconditioned seed; X1= moisture content of the unconditioned seed (expressed as a fraction); X2= moisture content of the seed after conditioning (expressed as a fraction); A= mass of water to add to achieve desired moisture.

To calculate the volume of water to be added, the following expression was used:

Volume of water to be added= mass of water to be added/water density at 20 °C (0.99823).

The amount of water to be added per sample was calculated to reach 12% humidity; the distilled water was added with a 1 mL syringe. The conditioning of a sample of 35 g of grain was carried out 4, 8, 12 and 24 h before determining the humidity of each sample by the stove method. To determine the humidity, 2 g of grain were used, 130 °C in the convention oven for 2 h, each determination was made in duplicate. The variable that was measured was grain moisture content on a dry basis.

A completely czar experimental design with factorial with four repetitions was used.

Experiment III. Amount of expansion of amaranth grain by effect of sample size and grain moisture.

The factors of moisture content of grain (CHUM) and weight of the sample (PMUES) in the variety ‛Laura’ were studied. The CHUM was modified with the formula of mass balance at 10, 12, 14 and 16%, in samples of 15 and 30 g of seed. The trapping of the grain was carried out with a portable hot air fluidized bed amaranth trap machine from the Postgraduate College. The temperature for the trapping was 232 °C. After the trapping, the grain was screened with a sieve of physical tests number 16 (Montiel inoxidables, Mexico), opening of 1.19 mm. The grain retained in the sieve was considered burnt grain and what happened as un-cut grain. The weight (g) and the volume (mL) of both portions were quantified. The grain volume was measured with a 250 mL graduated cylinder.

The variables that were measured in each sample were 1) volume of expansion, dividing the volume of the burnt grain on the original weight of the sample and expressed in mL g^{-1}; 2) yield of burnt grain, expressed as percentage of weight which was calculated by dividing the weight of burnt grain on the weight of the sample and multiplied by one hundred; and 3) percentage of untrimmed grain was calculated by dividing the weight of the untrimmed grain on the weight of the sample and multiplied by one hundred. A factorial experimental design completely to the random with three repetitions was used. Each observation was determined in duplicate.

In all the experiments, an analysis of variance was performed to determine differences between treatments. The least squares adjusted means for the main effects and interactions were compared with the Tukey test. For the calculation, the GLM procedure and the LSMEANS statement of the SAS program (SAS Institute, 2004) were used.

Experiment I. The analysis of variance (Table 1) showed that the main effects of all variables evaluated were highly significant ($p\leq 0.01$). In the double interactions, TEMP x PMUES was not significant, TEMP x PMUES was significant ($p\leq 0.05$) and the rest was highly significant ($p\leq 0.01$). In the triple and quad interactions there were no significant effects.

Table 1. Mean squares of the analysis of variance of the amaranth grain humidity variable by effect of stove temperature, variety, sample weight and oven drying time.

Fuente de variación	Cuadrado medio
Temperature (°C)	44.5253 **
Variety	127.3608 **
Sample weight (g)	3.2682 **
Drying time (h)	11.2497 **
Temperature × variety	0.3444 **
Temperature × sample weight	0.0008 ns
Temperature × drying time	0.2593 **
Variety × sample weight	2.1286 **
Sample weight × drying time	0.0102 ns
Temperature × variety × sample weight	0.0450 ns
Temperatura × variedad × tiempo de secado	0.0961 ns
Variety × sample weight × drying time	0.0021 ns
Temperature × sample weight × drying time	0.0226 ns
Temperature × variety × sample weight × drying time	0.0599 ns

Mean square of error 0.0765014; coefficient of variation= 2.6. *= $p\leq 0.05$, **= $p\leq 0.01$; ns= not significant. R^2= 0.982.

In all the tests comparing means of the main factors, significant differences were observed between treatments ($p\leq 0.05$). In TEMP the grain moisture obtained at 130 °C was higher. The CHUM was 11.4 and 9.88% with 130 and 103 °C, respectively. In the factor varieties (VAR), ‘Nutrisol’ had higher CHUM (11.93%) than ‘Laura’ (9.35%). The grain humidities determined in each sample size were different. In the 2 g sample, the CHUM was greater than in 5 g, with 10.87 and 10.44%, respectively.

In TSEC there were significant differences, the higher the TSEC the greater the CHUM of the grain. The time of 4, 2 and 1 h had 10.95, 10.32 and 9.58% humidity, respectively. In the treatment of 4 hours of drying extracted more moisture, but there may be loss of other elements other than water.

In the interaction of VAR x TEMP significant differences were found ($p\leq 0.05$) between treatments. The CHUM in each variety changed depending on the temperature used, being greater than 130 at 103 °C. The CHUM of ‘Laura’ was greater than that of ‘Nutrisol’. No significant interaction was found between TEMP and PMUES (Table 2), PMUES were modified in a similar way in each TEMP. The analysis of means showed significant differences ($p\leq 0.05$) among all the treatments. The combination 2 g of sample size and 130 °C was the most efficient in extracting moisture from the grain when this was established 11.28%.

Table 2. Averages of grain moisture in the sample temperature and weight combinations.

Temperature (°C)	Sample weight (g)	Humidity (%)	
130	2	11.28	a
130	5	10.85	b
103	2	9.7	c
103	5	9.28	d

Averages with the same letter in columns are statistically equal ($p< 0.05$).

In the combination of TEMP and TSEC (Table 3) there was statistical significance, the grain moisture determined in each TSEC changed according to the TEMP. In the comparison of means, the treatment that extracted the most water was 4 h and 130 °C ($p\leq 0.05$). The treatment that the youngest CHUM obtained was one hour at 103 °C. The treatments of 1 h at 130 °C with that of 4 h at 103 °C were statistically equal. The treatment of 4 h at 130 °C was the most efficient in extracting water from the grain. The treatment that follows in efficiency is 2 h at 130 °C. Therefore, it is more efficient to use 130 °C and 2 hours of drying. The latter is also recommended by Zapotocizn (2006) and ISTA (1993).

Table 3. Averages of grain moisture in the combination of temperatures and drying times.

Temperature (°C)	Drying time (h)	Humidity (%)	
130	4	11.68	a
130	2	11.22	b
130	1	10.3	c
103	4	10.22	d
103	2	9.41	e
103	1	8.86	f

Averages with the same letter in columns are statistically equal ($p< 0.05$).

The analysis of variance indicated interactive effects between VAR × PMUES, the grain CHUM of the varieties was different in different sample sizes. In ‘Nutrisol’ there were no differences between sample sizes ($p\leq 0.05$), but in ‘Laura’ higher humidity was determined in 2 g (9.72%) than in 5 g (9.97%). In the VAR × TSEC interaction there were significant differences ($p\leq 0.05$) between all the combinations (Table 4). Two groups were observed, one formed by the variety ‘Nutrisol’ and the other by ‘Laura’. In each variety, a higher TSEC produced greater grain CHUM.

Table 4. Averages of grain moisture in the interaction varieties × drying times.

Variety	Drying time (h)	Humidity (%)	
‘Nutrisol’	4	12.22	a
‘Nutrisol’	2	11.67	b
‘Nutrisol’	1	10.95	c
‘Laura’	4	9.68	d
‘Laura’	2	8.97	e
‘Laura’	1	8.21	f

Averages with the same letter in columns are statistically equal ($p< 0.05$).

In the PMUES × TSEC interaction the mean comparison test (Table 5) showed that the best treatment was 2 g and 4 h ($p \leq 0.05$), the second was 5 g and 4 h and the third was that of 2 g and 2 h. In the treatments of 4 h of drying a change of coloration in the grain was observed. The treatment with the lowest grain moisture was that of 5 g and 1 h.

Table 5. Averages of grain moisture in the interaction sample weights × drying times.

Sample weight (g)	Drying time	Humidity (%)	
2	4	11.14	a
5	4	10.76	b
2	2	10.53	b
5	2	10.1	c
2	1	9.81	c
5	1	9.35	d

Averages with the same letter in columns are statistically equal ($p < 0.05$).

Experiment II. In Table 6 it is observed that there were highly significant differences ($p \leq 0.01$) in the source of target moisture variation, but there were no significant differences for TACOND and the target moisture interaction × TACOND.

Table 6. Mean squares of the analysis of variance of the amaranth grain moisture variable for conditioning effect by mass balance and hours of conditioning.

Source of variation	Middle square
Target humidity (%)	65.9553 **
Time after conditioning (h)	0.0337186 ns
Target humidity × Time after conditioning	0.1299017 ns

Mean square of error 0.1295524; CV= 2.61674. *= $p \leq 0.05$; **= $p \leq 0.01$; ns= not significant.

The conditioning modified the humidity of the grain. There were significant differences ($p \leq 0.05$) between treatments. The treatments to modify the humidity of 12, 14 and 16% induced a humidity of 12.3, 13.79 and 15.17%, respectively. When calculating a 95% confidence interval, it was obtained that for the average of 12.3% this was from 12.17 to 12.43%, for 13.79% from 13.66 to 13.92% and for 15.17% from 15.04 to 15.3%. It is observed that the grain humidity obtained from 12.3, 13.79 and 15.17% differ from 12, 14 and 16%, respectively, which indicates the procedure worked, but the procedure must be adjusted.

In the TACOND factor there were no significant differences ($p < 0.05$) between treatments in grain moisture, the grain moisture determined for treatments 4, 8, 12 and 24 h was 13.81, 13.72, 13.74 and 13.75%, respectively; that is, the times evaluated after conditioning did not affect the grain moisture content, which may be due to the fact that water diffusion within the grain occurs within the first four hours. Balmaceda *et al*. (2015) found that equilibrium moisture was reached at approximately 4 h at 35 and 40 °C. Then, with at least four hours prior to the grain trapping, grain moisture can be modified and homogenized with the sample size used.

Experiment III. The analysis of variance on amaranth trapping due to the effect of PMUES and CHUM (Table 7) showed only highly significant differences ($p \leq 0.05$) in the source of variation CHUM in the variable volume of expansion. In the rest of the variables evaluated there were no significant differences. The PMUES variation factor and the PMUES × CHUM interaction did not show significant differences in any of the variables measured.

Table 7. Mean squares of variance analysis of variable volume of expansion of amaranth grain, yield, percentage of non-burst grain by effect of sample size and grain moisture.

Source of variation	Middle square		
	Expansion volume (mL g^{-1})	Yield (%)	Percentage of untrimmed grain (%)
Sample weight (g)	0.00113 ns	1.4743 ns	1.4743 ns
Grain humidity (%)	1.92551 **	2.7102 ns	2.7102 ns
Sample weight × humidity	0.16801 ns	1.3749 ns	1.3749 ns
Coefficient of variation	4.99	1.33	18.85

*= $p \leq 0.05$; **= $p \leq 0.01$; ns= not significant.

There were only significant changes in the volume of expansion, but not in the yield of burnt grain by changing the CHUM of the grain. In the mean comparison test, the highest expansion volume (7.05 mL g^{-1}) was obtained with 12 and 14% humidity. This same result is reported by Zapotoczny *et al*. (2006); Lara and Ruales (2002). In the variables yield of burnt grain and percentage of untrimmed grain there were no changes when modifying the humidity of the grain, possibly due to the fact that the lack of water in the grain at 10% humidity does not allow to gelatinize all the starch and to 16% there is excess of water, which causes a premature rupture of the pericarp (Lara and Ruales, 2002; Zapotoczny *et al*., 2006).

In the PMUES variation factor, no differences were found ($p < 0.05$) between 15 and 30 g for the variables volume of expansion, yield and percentage of non-burst grain. Therefore, to evaluate expansion volume, 15 g can be used as the sample size.

Conclusions

The combination of factors that worked best for moisture determination of amaranth grain in the oven was 2 g of sample, 2 h of drying at 130 °C.

It is possible to modify the moisture content of adding water with the mass balance formula.

No differences were found in the grain moisture content due to the effect of different rewetting times evaluated prior to the determination of humidity.

The moisture content affected the trapping of grain, being 12 and 14% the humidity that resulted in a greater volume of trapping.

There was no difference in the volume of trapping grain obtained for the sample sizes of 15 and 30 g, so it is possible to use a 15 g sample to evaluate the grain trapping.

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