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EFFECTS OF POPPING AND EXTRUSION PROCESSES ON SOME HYDRATION PROPERTIES OF *AMARANTH*

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Abstract - The effects of popping and extrusion processes on some of the hydration properties of *Amarantus cruentus,* which had already been degermed and dehulled, are discussed. Response surface methodology was used to analyse the effect of process variables (temperature and moisture) on hydration properties, evaluated by water solubility (S) and by amylographic retrogradation (R) .
Results show that precooked flours obtained by popping have a very high suspension consistency with low or intermediate S, while those obtained by extrusion have very high S but a much lower suspension consistency. The high S values for extruded samples are even higher than those for extruded waxy types of cereals.
The effects of the variables on each response depend on each case. S increases as temperature (T) and moisture (M) increase in both processes, although in extrusion, a maximum value was observed at 200 ºC and about 15% M. On the other hand, an inverse variable effect is observed for R; a minimum value is observed with extruded samples at about 14% M and for the whole T range, while a typical saddle-shaped surface is obtained for popped samples, with maximum values found at about 14 % and 18 % M for the two extreme T values, the highest and lowest, respectively. Another interesting effect is that the S-R pair values corresponding to popped samples do not fit the correlation between S and R, normally found with extruded samples. We can conclude that with the application of both processes it is possible to obtain precooked flours that have a wide range of hydration properties.
Keywords: extrusion, popping, amaranth.

INTRODUCTION

Amaranth has been produced in America and Africa for centuries (Bressani et al. 1987). The grains contain approximately 15% protein and 63% starch (on a dry basis). The starch has waxy characteristics and the protein is of a rather good quality with sulphur amino acid and lysine contents of about 4.4 and 5.0 (g per 100 g of protein), respectively (Teutónico and Knor, 1985; Lehman, 1996; Sanders and Becker, 1984; Becker et al. 1981; Betschart et al., 1981). Taking into account the good quality of its proteins and the interesting characteristic of its starch and the need to increase the utilization of the grain, a differential dry milling process was developed. It used a disc-type mill and grain conditioning, which allowed two different fractions to be obtained from the grains: a protein-rich one, containing more than 40% protein and a starchy fraction, containing about 79% starch (Tosi et al. 2000). This latter fraction, which is essentially the degermed and dehulled grains, can be considered a

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good raw material to produce a pregelatinized flour. Moreover dry-precooking processes, such as popping and extrusion, can modify the hydration properties of the raw material and consequently can be used for the production of pregelatinized flours (Koeppe et al. 1987; Mendoza and Bressani, 1987; Tosi et al. 1996).

The objective of the present work was to compare the effects of these two processes on the characteristics of the starch-rich fraction.

MATERIAL AND METHODS

Grains of *Amarantus cruentus* were degermed and dehulled in a disc-type mill to obtain the starchy fraction, as described previously (Tosi et al. 2000). The composition (on a dry basis) of this fraction, determined according to AACC methods (AACC, 1994) was 79.0% starch, 6.7% protein (N% x 6.25), 1.7% ash and 4.3% oil (soluble hexane fraction). This fraction was the raw material for the extrusion and popping processes. Extrusion was carried out in a 10 DN Brabender extruder with a 3:1 compression ratio screw at 173 rpm using a 3 mm diameter die. Popping was carried out using the fluidized bed equipment described previously (Tosi et al. 1982 and 1996). Extruder barrel temperature and the fluidizing air temperature together with the raw material moisture were varied according to the experimental design. A two-factor experimental design 3^2 with a triplicate central point was used for each process to analyse its effects on some hydration properties, with temperature (T) and moisture content (M) as independent variables. The T and M ranges for popping were 190-210 ºC and 12-20%, respectively, and for extrusion, 150-200 ºC and 12-20%. Eleven experiments were conducted for each case. All samples were left in ambient air until equilibrium (final moisture was in the range of 10%). After that, samples were milled in a CICLOTEC mill and the hydration properties of the flour obtained were evaluated using the suspension consistency measured by amylographic retrogradation at 30ºC (R) and water solubility (S), which were taken as dependent variables or responses. S was determined using a modified Anderson method and R in a 8.6% solids suspension. A description of the methodology can be found elsewhere (Anderson et al. 1970; González et al. 1986 and 1987). S and R average values from duplicates were used to obtain the surface responses for each process, using the statgraphic program V3.0

RESULTS AND DISCUSSION

Tables 1 and 2 show the results of the eleven experiments corresponding to the extrusion and popping processes, respectively. It can be observed that precooked flours obtained by popping have a very high suspension consistency with low or intermediate S values, while those obtained by extrusion have very high S but a much lower suspension consistency. The high S values for the extruded samples are even higher than those for extruded waxy types of cereals (González et al. 2000), suggesting that the endosperm structure of Amaranth is much weaker than that of waxy cereals. This is also in agreement with the fact that hard grains like popcorn varieties need much higher temperatures for popping.

Results of the ANOVA indicate that the two variables significantly affect S and R in both processes, with p values lower than 0.02 for most of the regression coefficient model (surface response). In only four cases were the p values higher: a) the coefficient of T^2 for R corresponding to extrusion with a p value of 0.0637, b) the coefficient of T for R corresponding to popping with a p value of 0.3848, c) the coefficients of T^2 and TxM for S corresponding to popping with p values of 0.8625 and 0.4097, respectively . The lack of fit for the four models was not significant at a confidence level of 95%, except for S corresponding to extrusion. These results allows us to compare the effects produced by the two processes.

The response surfaces of R and S for both processes are shown in Figures 1, 2, 3 and 4.

The variable effects on each response are different in each case. S increases as T and M increase in both processes, although in extrusion, a maximum is observed at 200 ºC and about 15% M. On the other hand, an inverse variable effect is observed for R. There is a minimum value with extruded samples at about 14% M and for the whole T range, while a typical saddle-shaped surface is obtained for popped samples, with maximum values found at about 14% and 18% M for the two extreme T values (the highest and the lowest, respectively). This type of response for extrusion is in agreement with that found with maize and rice grits (González et al. 1987; González et al. 2000), where S and R are inversely related and the degree of cooking can be represented by the two parameters. High S and low R values correspond to a high degree of cooking and vice versa. In the case of the extrusion of maize grits, the maximum degree of cooking is also obtained at a high temperature and about 15 %

moisture, but with much lower S values than for amaranth. In the case of popping, the complex type of response for R could be attributed to the different cooking mechanism for each process. The biggest changes (cooking) in extrusion occur inside the extruder, while in popping they occur during the explosion, in which T and M affect not only the development of pressure, but also the mechanical properties of the material. These different mechanisms produce different product structures and consequently different shape and size distributions of the particles obtained after the sample milling (CICLOTEC) and could contribute to different responses in the suspension consistency. This explanation is supported by the fact that the S-R pair values corresponding to popped samples do not fit the correlation between S and R normally found with extruded samples (González, 1981).

Table 1: Results with extruded samples

T ºC	M %	R BU	S %
175	16	225	82.6
175	16	220	82.2
175	12	260	77.8
175	16	230	81.6
200	20	380	78.6
150	16	200	76
200	12	230	80.9
150	20	305	79.5
200	16	250	80.5
175	20	380	77.9
150	12	275	61.9

Table 2: Results with popped samples

T ºC	M %	R BU	S %
190	12	1140	7.5
190	16	2080	16.4
190	20	2070	19.3
200	12	970	11.5
200	16	1850	21.8
200	16	1970	23.3
200	16	1860	20.4
200	20	1480	23.5
210	12	1900	16.1
210	16	1880	24.4
210	20	1690	30.9

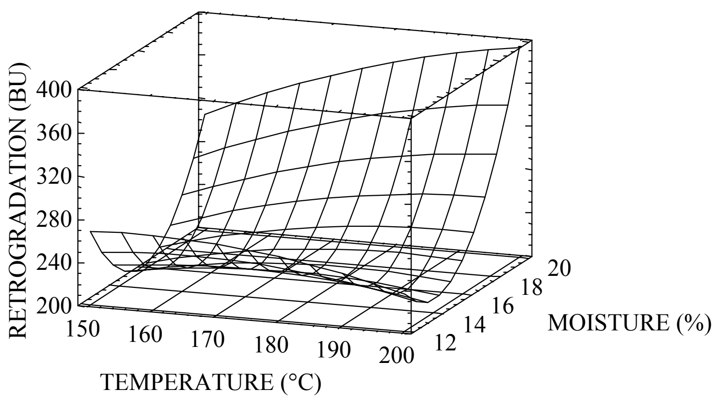

Figure 1: Retrogradation response surface for extruded samples

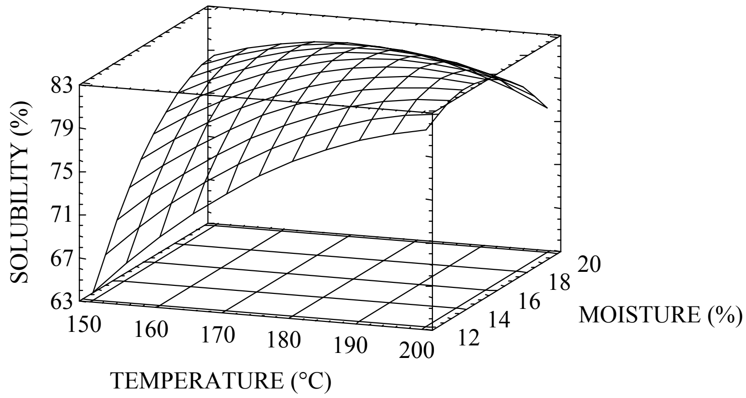

Figure 2: Solubility response surface for extruded samples

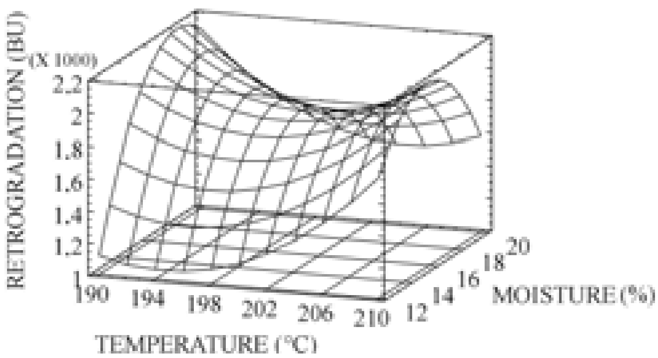

Figure 3: Retrogadation response surface for popped samples

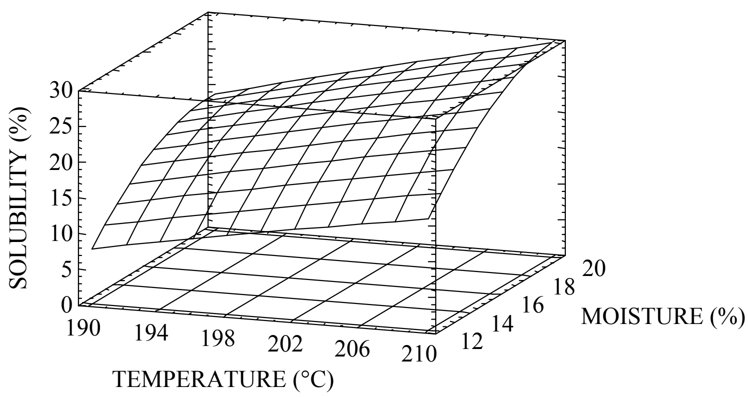

Figure 4: Solubility response surface for popped samples

CONCLUSION

We can conclude that with the application of both processes it is possible to obtain precooked flours that have a wide range of hydration properties. Precooked flours obtained by popping have very high suspension viscosities with low or intermediate S, while those from extrusion have very high S but a much lower suspension viscosity. The high S values for extruded samples are even higher than those for extruded waxy types of cereals. This suggests that the different cooking mechanisms involved in each process are the reason why the R responses are not similar.

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