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Pre-processing of aged carioca beans: Soaking effect in sodium salts in the cooking and nutrition quality

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Abstract

Increasing in cooking time of bean grains during storage is a feature of this legume. However, its long cooking process consequently makes many consumers often avoid eating this product, which results postharvest losses. The possibility of offering a product previously processed is an option for consumers who look for convenience and quality. One way to reuse the grains that already present hardening defect is the application of processes, such as soaking in sodium salts to reduce the cooking time. The objective of this study was to verify the effect of the pre-processing of the aged carioca beans using the soaking in sodium salts followed by drying under the parameters of technological quality, proteins and tannins content. It was used a screen design 2^2, with axial points ($\alpha = 1.41$), to determine the effect of concentration factors of sodium chloride (NaCl) and sodium bicarbonate ($NaHCO_3$) (0 to 4.5% for both the salts) used in the soaking of the aged grains, over the parameters: percentage of water soaking before cooking, cooking time, index of damaged grains, colour parameters and protein and tannin contents in the grains. The increase in concentration of $NaHCO_3$ from 0 to 4.5% reduced 9.06 min the cooking time of the aged bean grains. However, the same salt contributed to the increased darkening of the tegument of the grains, and in concentrations above 0.65% of $NaHCO_3$ pronounced darkening occurred in the product. The protein and tannin contents of the grains were not altered significantly in the employed process conditions.

Key words: *Phaseolus vulgaris*.L, cooking time, experimental design.

Introduction

Beans are an important food in the diet of populations, since apart from providing minerals, fibres, vitamins, they are a source of proteins. However, in many cases, there is non-acceptance and decrease in the consumption of grains that present reduced cooking quality. The storage of beans under improper conditions of temperature and humidity, results in the reduction of the quality due to changes in colour, flavour and consistency of the broth, and especially in the significant increase in cooking time [1]. A defect known as hard-to-cook (HTC) occurs in this legume, which causes changes in the tegument and cotyledons of the beans, increasing the preparation time which can lead in some cases, to postharvest losses of this product [2]. The bean quality can be determined primarily by the acceptability, given by the characteristics of cooking time, water absorption, colour of the product, as well as its nutritional characteristics. However, cooking and even nutritional quality changes during the storage of the product [1, 3, 4].

The implementation of combined chemical and physical processes can lead to reduction of the cooking time, facilitating the cooking process and obtaining a product of greater consumer acceptance. The soaking of the beans is a common practice used to soften the texture and speed up the cooking [5, 6]. The applications of this, associated to the use of solutions containing salts such as sodium chloride and sodium bicarbonate, have been tested and are presented with an alternative for reducing the cooking time of peas and of aged bean grains [7-9]. At the end of the process of soaking, when the goal is to present pre-processed grains in dry form, the drying step can be applied, since this enables quality assurance of the product during storage [10].

The objective of this study was to evaluate the effect of the pre-processing of aged beans using the soaking in sodium salts followed by drying under the parameters of cooking and nutritional quality.

Material and Methods

The experiment was conducted at the Laboratory for Quality Control of Agricultural Products of the Western Paraná State University (UNIOESTE) on bean grains (*Phaseolus vulgaris* L.) cultivar ‘IAPAR 81’ carioca group, grown in commercial area, in Santa Tereza do Oeste - Paraná, Brazil, in the latitude 25°10'41.05" S and longitude 53°32'45.82" W.

Storage of the grains: After harvest, the grains were dried through natural drying process under ambient conditions, the water content of the raw material was 12% determined by the oven standard method [11]. The grains were placed in kraft paper bags and stored for a period of seven months under ambient conditions in the laboratory.

Pre-processing: After the storage, the aged beans were subjected to pre-processing using the soaking in solutions of sodium salts, containing sodium chloride (NaCl) and sodium bicarbonate ($NaHCO_3$) at concentrations of 0, 0.65, 2.25, 3.85 and 4.50%. In the pre-processing, there were used 100 g of beans, placed in beaker containing 400 ml of macerating solution prepared in function of the combination of the salt amounts used in the statistical design of the experiment. The soaking period was set at 8 hours at room temperature conditions. After the soaking, the excess of water was removed, and the grains were placed in PVC braided packing and sent to the drying process. Drying was performed in a fixed bed using an air circulation oven (60±1°C). During the drying process, inspections were carried out in the grains and measurement of the mass was performed until the grains reach approximately the initial mass of the process.

Quality analysis: After the pre-processing and drying, the beans were subjected to quality analysis. The determination of the percentage of water soaking before the cooking (WSBC) was performed according to the methodology proposed by Carbonell *et al.* [3]. The average cooking time (CT) of the grains was determined with adapted Mattson cooker, following the method proposed by Proctor and Watts [12]. The rate of damaged grains (DG) after pre-processing was determined using the adapted methodology of Carbonell *et al.* [3]. After drying, the grains were manually separated into two portions: damaged and undamaged. For the classification of damaged product, there were considered the presence of cracks, loosening in the tegument and the presence of some bands (broken beans). The masses of the two portions were measured and the rate of damage grains was expressed as a function of the total mass of the grains. The product colour was determined through direct reading of the bean grains in a Konica Minolta ® colorimeter, CR410, with aperture of 50 mm, which considers in its system the coordinates L*, a* and b*, responsible for the brightness, content of red-green and content of blue-yellow, respectively. The apparatus for granular type (model CR-A50) was previously calibrated in a ceramic plate according to the predetermined patterns (Y= 85. 8; x = 0.3195; y = 0.3369) using the illuminant D65, which represents the average daylight and the readings performed in triplicate [13]. The values of the hue angle or coloration (H*) of the samples were determined by the expression:

$$H^* = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (1)$$

in which H* = angle of coloration or chromatic tonality colour; b*= component of the colour red-green; a*= component of the colour yellow-blue;

The chroma index parameter (C*), which indicates the chromaticity or colour intensity of the sample was also determined from the results of a* and b* attributes, using the following expression [13]:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (2)$$

in which C* = chroma index; b* = component of the colour red-green; a*= component of the colour yellow-blue;

The colour difference between the grains and the pre-processed grains was determined through the following expression [14]:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (3)$$

in which

ΔE* = colour difference compared to control;

ΔL* = difference between the brightness of the sample compared to the control;

Δa* = difference between the component a* of the sample compared to the control;

Δb* = difference between the b* component of the sample compared to the control.

Determination of chemical composition: For the chemical analyzes of the grains, the samples were allowed to rest for 12 hours at room temperature and crushed and sieved through a 50-mesh sieve. The protein content was quantified according to the micro-Kjeldahl method, being the content of nitrogen multiplied by the conversion factor 6.25 [15]. The determination of the tannins of the grains was performed using the methodology described by Ranilla *et al.* [16], through the extraction with methanol and subsequent colorimetric reaction with sodium carbonate solution and Folin-Denis reagent and read at 560 nm. Tannic acid was used to construct the standard curve, and the results were expressed in tannins $mg.g^{-1}$ of sample. All analyses, except the index of damaged grains and colour variation, were also performed on a sample of unprocessed grains, considered in this experiment as control.

Experimental design: The response surface methodology (RSM) was used to evaluate the influence of the factors of NaCl and concentration of $NaHCO_3$ used for soaking in the pre-processing, on the analysed responses. A central composite rotatable design (CCRD) 2^2 was used , with axial points with concentrations between 0 and 4.5% for the lower and upper levels, respectively. The planning matrix is presented in Table 1 with the main experiment, 4 experiments under the axial conditions and 3 repetitions at the central point, totalling 11 experiment conducted in randomized way. RSM is currently one of the most popular optimization techniques in field of food science because of its comprehensive theory and the most common experimental design used in RSM is the CCRD which has equal predictability in all directions from the centers. The numbers of experimental points in the CCRD is sufficient to test statistical validity of the fitted model and lack-of-fit of the model [1]. The statistical analysis was performed with

Table 1. Rotatable central composite design (RCCD) arrangement.

Experiment	Coded *		Uncoded levels	
	X_1	X_2	% NaCl	% $NaHCO_3$
1	-1	-1	0.65	0.65
2	1	-1	3.85	0.65
3	-1	1	0.65	3.85
4	1	1	3.85	3.85
5	0	0	2.25	2.25
6	0	0	2.25	2.25
7	0	0	2.25	2.25
8	-α	0	0.00	2.25
9	+α	0	4.50	2.25
10	0	-α	2.25	0.00
11	0	+α	2.25	4.50

* X_1= concentration of NaCl and X_2 concentration of $NaHCO_3$ in the macerating solution; $\alpha = (2^n)^{1/4} = 1.41$.

Statistical software version 7.0, by calculating first the main effects of the factors and of the interactions on the analysed responses, considering a significance level of 10% ($p<0.10$). Second-order models containing only significant terms were adjusted and their coefficients evaluated by the "t" test [17, 18]. To verify the statistical validity and the lack-of-fit (predictive ability) of the models, it carried out the Fischer (F) test, calculated in the analysis of the variance (ANOVA) and it was compared this value with the tabulated value corresponding to the adopted confidence level. The model was considered predictive when the ratio between the calculated F value (F_{cal}) and of tabulated F (F_{tab}), that is F_{cal}/F_{tab} was greater than or equal to 1 [17].

Results and Discussion

The results obtained from the design CCRD 2^2 for the dependent analysed variables after pre-processing of the aged bean grains under conditions of soaking in saline solutions with the characterization of the control grains are presented in Table 2. For the quality parameter percentage of water soaking before the cooking, variation was verified from 96.22 to 113.80 % under the conditions of the experiment 04 and 11, respectively. For the aged bean grains considered as control, the value was of 110.90 %.

The cooking time of bean grains, after a period of seven months of storage under ambient conditions, was equal to 42 min (Table 2). With the pre-treatment using the soaking in the aged grains in solutions containing NaCl and $NaHCO_3$ followed by drying, resulted in a reduction in the cooking time. For this parameter occurred variation between 9 and 24 min (under the conditions of the tests 11 and 10, respectively) occurring in all the performed trials, reduction in the time of cooking of the pre-processed grains when compared to the unprocessed grains (Table 2).

The contents of damaged grains after the pre-processing varied between 3.72 and 9.53% for the test conditions 11 and 08, respectively (Table 2). According to Cai and Chang [19], the drying process apart from presenting a direct effect on the final moisture content of dried beans also influence the amount of defects in the product. The separation between the cotyledons and the fissures in the bean seed coat are mainly related to the interactions between steam pressures present in the grain and in the drying air [20]. Therefore, lower rates of damage in grains after the process are are expected, thus reducing the losses with raw material after pre-processing of the beans. According to Corte *et al.* [6], this parameter must be evaluated after the processing, since it is an important quality characteristic for all types of pre-processed bean, for example canned, frozen or dry type, being therefore maximized during the process.

In the colour parameters, it was noted that for all performed tests, there was a reduction in the brightness (luminosity) when it was compared to the pre-processed grains, that presented variation between 36.56 and 45.29, with the control grains that presented the value of 46.33 (Table 2). In the samples of pre-processed grains the occurrence of pronounced darkness was verified due to marked decrease of the brightness in the product. For chroma index (C*) and colouring angle (H*), decreases in their values were also observed in relation to the control verifying a variation among the tests from 11.74 to 17.34 for the first and from 40.52 to 55.70, for the second parameter. The chroma parameter is indicative of the colour intensity perceived by the human vision, the higher the value from parameter the greater the chromatic tonality of the samples, now the H* parameter is understood as tonality and defines the basic colouring of the sample [13].

The difference in colour of the pre-processed bean grains in relation to the product without processing (ΔE*) ranged between 2.00 and 12.28 (tests 10 and 03, respectively). The higher the presented value by the difference of colour, the most noticeable the differentiation between the samples.

The protein content in the unprocessed grains was equal to 26.49% (Table 2), while between the assays of pre-processing variation from 24.97 to 27.92% was verified. Rios *et al.* [1] found that the levels of crude protein were between 24.11 and 30.41%, the results obtained in this study remained within this range.

For tannins, in the control grains, an average concentration of 0.721 mg of tannic acid in 100 g of beans was observed. In the grains after the pre-processing, values were between 0.688 and 0.949 $mg.100 g^{-1}$. Silva *et al.* [21] verified for the BRS Pontal cultivar, also from the carioca group the amount of phenolic compounds (tannins) equal to 0.74 mg of $catequine.g^{-1}$ of sample. Delfino and Canniatti-Brazaca [22] observed mean values for tannin content in stored beans (180 days) equal to 0.90%, being therefore similar to those found for the processed grains. Phenolic compounds are present mainly in the bark of legumes, and directly related to the colouring of the grains, checking in grain with a darker coloration a highest concentration of tannins [21].

The independent variables, that is, the quality parameters evaluated that were significantly changed by the concentration factors of NaCl and concentration of $NaHCO_3$ used in the soaking are shown in Table 3. For the other parameters (index of damaged grains, chromaticity, colouring angle, proteins and tannins concentration), there were no significant effects of the factors at the adopted level of significance.

For the percentage of water soaking before the cooking, a negative effect of the use of NaCl salt in the soaking of aged bean grains (-2.58) was verified (Table 3). The concentration of $NaHCO_3$ also presented a negative effect for this response (-10.98), that is, for both the salts, the increase of the concentration from 0 to 4.5% caused a reduction in the hydration capacity of the grains. The model of the parameter is presented by the Equation 4 (Table 3), and it is observed that the linear term of the concentration factor of $NaHCO_3$ is higher when

Table 2. Parameters responses of technological, nutritional quality factors analysed in control and pre-processing carioca aged bean in condition of soaking in saline solutions followed by drying.

Experiment	WSBC	CT	DG	L*	C*	H*	ΔE*	Pt	CTan
01	112.68	22	7.25	41.91	16.74	49.26	5.43	25.46	0.688
02	111.35	17	7.22	40.42	15.88	46.52	7.31	26.80	0.716
03	102.93	14	6.94	37.16	11.81	41.61	12.28	26.45	0.833
04	96.22	10	5.88	37.22	11.80	43.70	12.08	27.92	0.892
05	104.00	20	7.03	37.08	14.03	40.52	11.42	26.36	0.915
06	101.69	16	8.09	37.05	13.88	42.34	11.32	25.96	0.949
07	101.65	17	5.68	36.81	13.69	41.95	11.63	26.00	0.806
08	103.56	15	9.53	36.56	13.51	40.66	12.03	28.56	0.725
09	101.95	10	5.64	37.14	14.05	42.61	11.15	24.97	0.938
10	113.80	24	5.96	45.29	17.34	55.70	2.00	26.45	0.689
11	100.40	9	3.72	38.01	11.74	42.54	11.62	25.93	0.750
Control	110.90	42	-	46.33	19.04	56.24	-	26.49	0.721

* WSBC: percentage of water soaking before the cooking (%); CT: grains cooking time (min); DG: damaged grains (%); L*: luminosity; C*: croma index; H*: colouring angle (degrees); ΔE*: colour difference in relation to the control; PT: proteins content (g/100 g) and CTan: concentrations of tannins (mg/100 g).

Table 3. Summary of multiple significant analyses of regression of the independent variables (VI) analysed after the pre-processing of the aged beans in saline solutions.

VI	Linear effects		Statistical parameters			
	NaCl (X_1)	$NaHCO_3$ (X_2)	R^2	F_{cal}	Equation	
WSBC	-2.58	-10.98	0.931	31.50*	$\hat{Y}$=102.79 –1.29 X_1–5.49 X_2 + 2.45 $(X_2)^2$	(4)
CT	-4.02	-9.06	0.926	29.48*	$\hat{Y}$ = 17.41 – 2.01 X_1 – 2.20 $(X_1)^2$ – 4.53 X_2	(5)
L*	-0.15	-4.57	0.981	119.62*	$\hat{Y}$ = 38.90 – 2.28 X_2 + 0.39 X_1. X_2 + 2.35 $(X_2)^2$	(6)
*ΔE**	0.11	6.31	0.985	155.75*	$\hat{Y}$ =11.54 + 3.16 X_2 – 0.52 X_1. X_2 –2.34 $(X_2)^2$	(7)

WSBC: percentage of water soaking before the cooking (%); CT: grains cooking time (minutes); L*: luminosity, ΔE*: colour difference in relation to the control. F_{tab} (3, 7, 0.10): 3.07, *significant (p<0.10).

compared to concentration factor of NaCl, being that the first also presented a significant quadratic term. The value of the adequacy measure of the fit, the determination coefficient (R^2) was equal to 0.931, so there is a good explanation of the total variation of the results. The regression for the WSBC of the grains was considered significant (F_{cal}/F_{tab} greater than 1) with the lack of non-significant fit, being the model considered predictive.

Considering that the quadratic model (Equation 4) has been validated, it was possible to generate the graphical representation of it, the response surface presented in Fig. 1A. It is observed that the addition in high concentrations of $NaHCO_3$ in the soaking followed by drying reduces the hydration ability of the aged bean grains.

For the time of cooking of the grains (CT), there were significant and negative effects of the sodium chloride concentration (-4.02) as it can be seen in Table 3. Therefore, this salt when used in the previous macerating solution of the product followed by drying helped to reduce the cooking time of the aged bean grains. Bertoldo *et al.*[8] investigated the addition of different concentrations of sodium chloride (0.50 and 125 g.L^{-1}) in the soaking and the effect of these conditions in the cooking time of aged grains and verified that the increase in the NaCl concentration in the macerating solution made possible the decrease in the cooking time, up to a maximum limit of 56.50 g.L^{-1}.

The concentration of $NaHCO_3$ also presented significant and negative effect on the cooking time. The change in concentration of $NaHCO_3$ from 0 to 4.5% reduces 9.06 min of the cooking time of the aged bean grains (Table 3). For this response, the analysis of regression was performed resulting in the encoded model of cooking time of the grains in function of the concentration of salts in the macerating solution, shown in the Equation 5 (Table 3). The same was considered significant since the relationship between entre F_{cal} and F_{tab} and was superior to 1, with lack of non-significant fit, being therefore predictive with determination coefficient of 0.926 and its surface shown in Fig. 2B. It is possible to observe the linear and negative effect of the $NaHCO_3$ concentration, that is, with an increase of the salt concentration occurs the reduction in the value of the evaluated response.

The effect of sodium salts in the reduction of the cooking time of the beans have been reported in other researches. Bassinello *et al.*[4] reported that the addition of salts in the soaking resulted in lower cooking times in aged common bean grains. Sodium bicarbonate when used in the processing of the beans contributes to the increase of the solubilisation of the pectin and of minerals such as Ca and Mg, thereby occurring a direct effect on the texture of the grain.

With regard to the colour of the product, for the luminosity parameter (L*) of the grains, there were analysed the effects of independent variables and of interactions, and it was observed that the use of sodium chloride didn´t present significant effect at the level of the adopted significance (Table 3). However, the salt concentration $NaHCO_3$ presented negative and significant effect (4.57). There was also a significant interaction between the salts as can be seen in the Equation 6 (Table 3). The fit of the response surface of luminosity in function of the two salts concentration presented a good level of significance (p<0.10) and the obtained model was considered predictive (Table 3) and being its curve of contour presented in Fig. 2A. When concentrations above 0.65% of $NaHCO_3$ were used in the solution of soaking of aged carioca bean grains, pronounced darkening occurred in the product (Fig. 2A).

For the colour difference of the processed samples in relation to the control grain (ΔE*), a significant effect was observed in the concentration of $NaHCO_3$ (Table 3). The response surface analysis for this parameter of response resulted in the model presented by the Equation 7 (Table 3), being the same considered significant (p<0.10) and predictive being its contour curves illustrated in Fig. 2B. It is verified that with an increase of the concentration of $NaHCO_3$, major changes occur in the colour of the pre-processed product in comparison to the control. The measures of differences in colour are important in the food process industry to verify changes occurring after the treatments, to which the product is submitted, being an attribute of primary sensory quality[14].

In relation to the other evaluated parameters, the effects of factors concentration of NaCl and $NaHCO_3$ were not significant (p>0.10). That is, the adopted levels for the aforementioned factors did not significantly alter the index of damage, chroma index (C*), the colouring angle (H*) and contents of proteins and tannins of the grains after pre-processing. There were no significant changes in the protein and tannin contents after the process, indicating that the pre-processing in saline solutions followed by drying may be an alternative to reduce the cooking time of the aged beans without altering the nutritional quality of the product.

Conclusions

Based on the results obtained, it can be concluded that the factors concentration of NaCl and $NaHCO_3$ presented, according to the obtained models, a strong influence on the parameters percentage of soaking water before cooking, cooking time, luminosity and colour difference of grains in relation to the control. The increase in concentration of $NaHCO_3$ in the soaking solution significantly reduced the ability of hydration and the cooking time of aged carioca bean grains. However, the same salt contributes to the

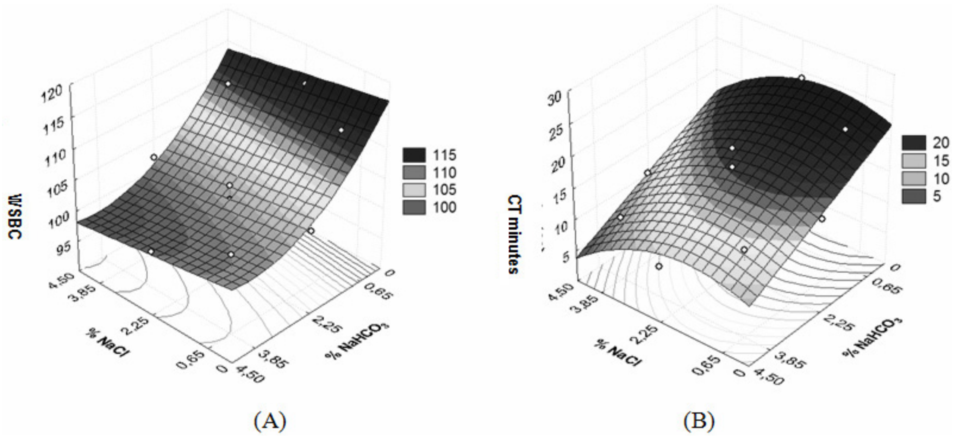

Figure 1. Response surfaces plot showing effect on water soaking before the cooking (A) and the cooking time CT (B) of the pre-processed beans in function of the concentration of NaCl and $NAHCO_3$ used in the soaking followed by dying.

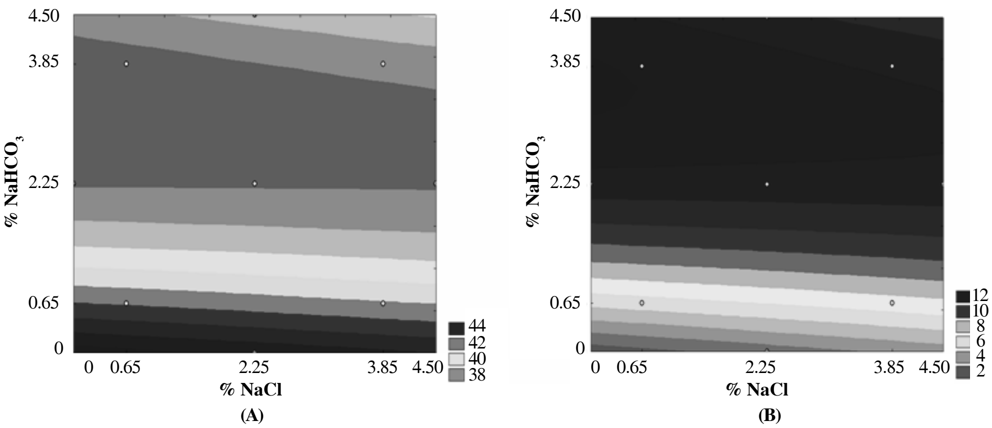

Figure 2. Curves of contour of the response surfaces for the parameters L*(A) and colour difference - ΔE* (B) of the pre-processed bean grains, in function of the concentration of NaCl and $NaHCO_3$ used in the soaking followed by drying.

increased darkening of the grain tegument thereby increasing the difference in colour compared to the unprocessed product. The content of proteins and tannins content of the grains was not changed significantly due to the employed process conditions.

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