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Effect of Roasting Process Variables on In-Vitro Protein Digestibility of Bengalgram, Maize and Soybean

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ABSTRACT

The effect of roasting process variables (temperature and time of roasting) on in-vitro protein digestibility of roasted and ground bengalgram, maize and soybean were studied. Roasting resulted in a slight increase in the PD value. Statistical analysis using an analysis of variance technique showed that the effect of time of roasting on the PD value of bengalgram and maize was more than that of temperature of roasting. An opposite trend was observed in the case of soybean.

INTRODUCTION

Roasted and puffed grains, in one form or another, are consumed not only in the Indian subcontinent and South Asian countries but more or less throughout the world. The mode of consumption depends on the availability of grains, convenience, locality and food habits of people.

Puffed paddy and rice are very popular in West Bengal (Ghose *et al.*, 1960), Bihar and Uttar Pradesh (Prasad & Srivastav, 1984). Bengalgram, maize, jowar, barley, redgram and millet are also puffed and consumed. Reports are available for the use of puffed and roasted wheat, corn, soybean and bengalgram in Nepal (Krantz *et al.*, 1983), and puffed rice, millet, sorghum, corn, wheat, soybean, mungbean, etc., in Korea (Patterson & Bray, 1985).

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Krantz *et al.* (1983) stated that, for old people, sometimes these roasted grains are ground to prepare a soft food called *Sattu.* Similar observations were made by Prasad and Srivastav (1984) in northern India.

Cooking by roasting and puffing is a typical high-temperature short-time process; it retains nutrients and inactivates growth inhibitors and contaminating microorganisms.

Roasting or puffing alters the nature of many of the food constituents such as starches and proteins by changing their physical, chemical and nutritional properties. It also changes the bio-availability of proteins, carbohydrates, lipids and vitamins.

Sometimes the desirability of the product increases due to these alterations. For example, a popular nutty flavour is developed (Krantz *et al.*, 1983), hardness of the product is reduced (Abdelrahman & Hoseney, 1984) and gelatinization of starch (Das & Srivastav, 1989) renders better palatability and chewiness.

Not much is known about nutritional aspects of the roasted or puffed products. Murthy and Kanthraj Urs (1980) and Krantz *et al.* (1983) measured available lysine as an index for protein quality. Besides this, estimation of in-vitro protein digestibility (PD) using enzymes is another acceptable and simple method for evaluating protein digestibility and availability (Hsu *et al.*, 1977) of many foods, including roasted and puffed grain products.

The present study was undertaken to evaluate the effect of roasting process variables (temperature and time of roasting) on the PD value of roasted and ground bengalgram, maize and soybean.

MATERIALS AND METHODS

Bengalgram, maize and soybean were purchased from the local market and analysed for their proximate composition following the AOAC (1980) methods. The grains were roasted and the proximate composition of the roasted grains was determined following the same AOAC (1980) methods.

The grains were adjusted to 12% moisture and roasted in 0·25:1 grain-to-sand ratios at 180, 215 and 250°C for 1·5, 2·0 and 2·5 min.

Preparation of roasted grain powder

The sequence of the processes used to produce roasted grain powder involved moistening, roasting and grinding. For moistening, the grains were dipped into water and free water was allowed to drain off. Moistened grains were heaped and kept overnight for moisture equilibration. The grains were

then roasted in an open aluminium pan using a gas burner. Hulls of bengalgram and soybean were separated by passing through a Burr mill having a pair of discs, of which one was stone and the other rubber. The cotyledons of bengalgram, soybean and maize were ground to powder in the same Burr mill after replacing the rubber disc by a stone disc.

Protein digestibility

The in-vitro protein digestibility (PD) was measured for raw and roasted grain powders according to the method suggested by Hsu *et al.* (1977). The digestibility values were determined at several combinations of the temperature and time of roasting. A 3^2 factorial design (Myers, 1971) was adopted and each experiment was conducted thrice. The values of PD reported here are based on the PD value of casein as 89·2.

Variability of the PD values with the temperature and time of roasting was determined by developing a quadratic response surface model.

RESULTS AND DISCUSSION

The proximate analysis of the grains is presented in Table 1. The PD values of raw and roasted bengalgram, maize and soybean are presented in Table 2. It is clear from the table that the PD values of all the grains increase after roasting. This increase is possibly due to destruction of protease inhibitors and opening of the protein structure. However, at high temperature and time of roasting, a reduced PD value was observed which might be due to non-enzymatic browning reactions and thermal cross-linking (Hsu *et al.*, 1977).

The temperature X_1 was coded as $x_1 = (X_1 - 215)/35$ and the time of roasting X_2 was coded as $x_2 = (X_2 - 2)/0{\cdot}5$. Since the values of X_1 were 180, 215 and 250°C, and those of X_2 were 1·5, 2·0 and 2·5 min, the values of coded variables x_1 and x_2 came out to be -1, 0 and $+1$.

TABLE 1
Proximate Composition of Raw Bengalgram, Maize and Soybean (%)

Component	*Bengalgram*	*Maize*	*Soybean*
Moisture	7·19	8·6	5·68
Protein	16·30	7·19	42·60
Fat	5·96	5·46	22·1
Ash	2·72	1·57	5·20
Carbohydrate by difference	67·2	77·2	24·5

TABLE 2
Effect of Process Variables on in-vitro Protein Digestibility

Temperature of roasting (°C)	*Time of roasting* (min)	*Protein digestibility*		
		Bengalgram	*Maize*	*Soybean*
Raw	Raw	68·0	59·0	72·8
180	1·5	79·2	77·8	83·7
180	2·0	78·7	76·4	83·3
180	2·5	78·1	75·6	82·5
215	1·5	79·2	77·6	82·7
215	2·0	78·5	76·4	81·7
215	2·5	77·8	75·4	80·3
250	1·5	78·3	76·4	81·8
250	2·0	77·4	75·1	80·2
250	2·5	76·6	73·4	78·3

Regression equations for the PD value of bengalgram (PD_b), maize (PD_m) and soybean (PD_s) in terms of coded variables were:

$$PD_b = 78{\cdot}51 - 0{\cdot}62x_1 - 0{\cdot}69x_2 - 0{\cdot}46x_1^2 - 0{\cdot}10x_1x_2 + 0{\cdot}10x_2^2 \quad (1)$$

Correlation coefficient = 0·96

$$PD_m = 76{\cdot}11 - 0{\cdot}67x_1 - 1{\cdot}10x_2 - 0{\cdot}73x_1^2 - 0{\cdot}25x_1x_2 + 0{\cdot}05x_2^2 \quad (2)$$

Correlation coefficient = 0·97

$$PD_s = 81{\cdot}66 - 1{\cdot}52x_1 - 1{\cdot}17x_2 + 0{\cdot}08x_1^2 - 0{\cdot}60x_1x_2 - 0{\cdot}17x_2^2 \quad (3)$$

Correlation coefficient = 0·99

Tables 3–5 show the analysis of variances for the roasting process variables at the coded levels of -1, 0 and $+1$.

It is observed from Tables 3 and 4 that the coefficients of x_1^2 and x_2^2 for bengalgram and maize in eqns (1) and (2) are non-significant. Negative values of the coefficients of the remaining variables indicate that increase in temperature and time of roasting will reduce the PD value of these grains. From these tables it is also observed that the F value for time, x_2, is greater than that of temperature, x_1. This suggests that the PD values of bengalgram and maize would vary more with time than with the temperature of roasting. The effects of interaction terms are found to be non-significant for both bengalgram and maize.

In the case of soybean the temperature seems to have a greater effect on the PD value than the time of roasting (Table 5). The interaction of temperature and time is found to have some effect on its PD value. The high values of correlation coefficients for the regression equations (1)–(3) show the adequacy of the regression model to predict the PD value of the roasted grains.

TABLE 3
Analysis of Variance for Protein Digestibility of Roasted and Ground Bengalgram

Source of variation	*Reduction in sum of square*	*Degree of freedom*	*Mean sum of square*	*F value*
x_1	2·32	1	2·32	20·27**
x_2	2·88	1	2·88	25·22**
x_1^2	0·42	1	0·42	3·67^{NS}
x_1x_2	0·04	1	0·04	0·21^{NS}
x_2^2	0·02	1	0·02	0·13^{NS}
Error	0·57	5	0·11	

F value (1, 5) = 16·26 (at 1%), 6·61 (at 5%).
** Significant at 1% level of confidence.
^{NS} Not significant.

In the actual level of variables the regression equations were also determined and simplified by sequential elimination of the term with the lowest F value. The process of elimination was continued until the combined contribution of the discarded terms remained insignificant at 95% confidence level. After eliminating the insignificant terms the following equations were obtained:

$$PD_b = 65{\cdot}04 + 0{\cdot}16X_1 - 0{\cdot}000\,4X_1^2 - 0{\cdot}006X_1X_2 \quad (4)$$
Correlation coefficient = 0·96

$$PD_m = 53{\cdot}04 + 0{\cdot}26X_1 - 0{\cdot}000\,6X_1^2 - 0{\cdot}01X_1X_2 \quad (5)$$
Correlation coefficient = 0·97

$$PD_s = 83{\cdot}53 + 5{\cdot}02X_2 + 0{\cdot}000\,06X_1^2 - 0{\cdot}034X_1X_2 \quad (6)$$
Correlation coefficient = 0·99

TABLE 4
Analysis of Variance for Protein Digestibility of Roasted and Ground Maize

Source of variation	*Reduction in sum of square*	*Degree of freedom*	*Mean sum of square*	*F value*
x_1	2·69	1	2·69	14·71*
x_2	7·24	1	7·24	39·54**
x_1^2	1·07	1	1·07	5·82^{NS}
x_1x_2	0·25	1	0·25	1·37^{NS}
x_2^2	0·01	1	0·01	0·02^{NS}
Error	0·73	4	0·18	

F value (1, 4) = 21·21 (at 1%), 7·11 (at 5%).
* Significant at 5% level of confidence.
** Significant at 1% level of confidence.
^{NS} Not significant.

TABLE 5
Analysis of Variance for Protein Digestibility of Roasted and Ground Soybean

Source of variation	*Reduction in sum of square*	*Degree of freedom*	*Mean sum of square*	*F value*
x_1	13·86	1	13·86	111·74**
x_2	8·14	1	8·14	65·64**
x_1^2	0·01	1	0·01	$0·06^{NS}$
x_1x_2	1·43	1	1·43	11·51*
x_2^2	0·06	1	0·06	$0·31^{NS}$
Error	0·62	5	0·12	

F value (1, 5) = 16·26 (at 1%), 6·61 (at 5%).
** Significant at 1% level of confidence.
* Significant at 5% level of confidence.
^{NS} Not significant.

The difference between the equations in coded and actual levels is due to the higher values of variables in actual level than those in the coded level. Since the correlation coefficients in the two sets of equations are the same, one can use either of the equations for finding out the protein digestibility of the roasted grains.

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