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Micronization of maize flour: Process optimization and product quality

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ABSTRACT

Micronization refers to high temperature short time processing of grains using near infrared rays. The present study is focused on optimization of process conditions for micronization of maize flour with an emphasis on enhancing rapidly digestible starch (RDS) content for enhancing starch digestibility and inactivation of peroxidase enzyme for probable extension of shelf-life. The study employed a central composite design (CCD) with three variables namely, time (60–180 s), temperature (130–170 °C) and moisture content (20–40%) with RDS and peroxidase contents as responses. The optimized micronization conditions (173 s, 159 °C, 40% mc; 164 s, 166 °C and 40% mc) resulted in 7.1–7.7% increase in RDS content and 92.5–96.2% inactivation of peroxidase enzyme, respectively, without significantly affecting protein, carbohydrate and fat content of flour. Validation studies showed that experimental values matched well with that of predicted, suggesting suitability of the model used. At the optimized conditions, micronization was also able to inactivate lipase activity by 66.9–68.2%.

1. Introduction

Thermal treatments of grains have gained new interest in recent years as one of the effective methods for inactivation of antinutritional factors, surface sterilization, improving nutritional quality and extending shelf stability. One such approach that has been recognized to have a niche in thermal processing of cereals and legumes is micronization. The term micronization often refers to a high temperature short time heat processing of grains using near infrared (NIR) rays. When high frequency NIR rays impinge upon grains, they induce the constituent molecules to vibrate, which leads to intermolecular friction, resulting in rapid heating of the material (Ginzburg, 1969). This rapid heating imparts some beneficial changes such as gelatinization of starch and inactivation of enzymes and antinutritional factors in grains processed. This IR portion of the electromagnetic spectrum has added new impulse in grain processing in many ways.

Infrared heating of cereal grains is mainly applied to partially gelatinize the starch for use in the production of breakfast cereals, as cereal adjuncts or as animal feed (Cruzy Celis et al., 1996). Infrared micronization offers many advantages over conventional heating. Infrared energy heats the product directly, without an intervening heat transfer medium such as air, enabling to achieve a high level of efficiency and faster cooking (Abe and Afzal, 1997; Pan et al., 2008). Results to date validate the use of this technology extensively for the preparation of pre-cooked grain legumes with substantially reduced cooking time. Micronization can produce an instantized product (Cenkowski and Sosulski, 1998), eliminating the need for overnight soaking and long cooking times. Previous research findings attribute reduced cooking time of micronized legumes to increased ability of micronized seed matrix to imbibe water and partial gelatinization of starch (Arntfield et al., 1997, 2001). Metussin et al. (1992) observed that micronization improved the protein digestibility and available lysine of soymilk prepared from micronized soybeans without inducing any marked changes in the molecular constitution of proteins. Micronization can be used for complete inactivation of antinutrients such as lectin and trypsin inhibitors (Kouzeh et al., 1982). Tannins were also inactivated by about 25% without affecting the available lysine content (Fasina et al., 2001). In the recent past, micronization has been widely used in processing of feed stuffs as it improves the digestibility of macromolecules. Studies on utilization of micronized grains as animal feed have reported increased *in-vitro* dry matter digestibility, gas production, degree of starch gelatinization and improved post ruminal supply of amino acid when compared

Abbreviations: CCD, central composite design; RDS, rapidly digestible starch; IR, infrared rays; NIR, near infrared rays; SDI, starch digestibility index; pNPA, p-Nitrophenyl acetate; mc, moisture content; HMT, heat-moisture treatment; SEM, scanning electron microscope; ANOVA, analysis of variance.

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to other methods such as dry rolling (Mustafa et al., 2002; McAllister and Sultana, 2011).

The existing research reports available on micronization are oriented mainly towards reducing the cooking time of pulses by improving the water penetrability in grains during cooking. Practically, there are no reports on optimization of processing conditions for micronization of maize flour with a focus on enhancing starch digestibility and enzyme inactivation. The objectives of the present study are: i) optimization of processing conditions such as temperature, process duration and moisture content for micronization of maize flour in order to enhance starch digestibility (by increasing RDS content) and inactivation of peroxidase enzyme that could increase the storage stability of flour and ii) to study the effect of micronization on composition (carbohydrates, protein, fat), micronutrient (total carotenoid content) and lipase enzyme.

2. Materials and methods

2.1. Materials

Maize (*Zea mays*), Nityashree variety (NAH, 2049) was sourced from ZARS Mandya, University of Agricultural Sciences, Bangalore, India. Enzymes such as pancreatin, amyloglucosidase, glucose oxidase, peroxidase, invertase were purchased from Sigma–Aldrich. All other chemicals and reagents used were of analytical grade.

2.2. Methods

Maize grains were powdered in a comminuting mill (Cadmach, Ahmedabad, India) and the flour was sieved (particle size 390–475 μm) and stored under refrigerated conditions until further use.

2.2.1. Pre-treatment

Maize flour was tempered prior to micronization using deionized water to achieve desirable initial moisture content (20–40%) and was stored at room temperature (25 ± 2 °C) for 1 h to facilitate the moisture distribution.

2.2.2. Infrared micronization

Maize flour was subjected to micronization in NIR (1.1–1.2 μm) based system (0.26 kW/m^2) fitted with quartz lamps as heat sources on either sides of the conveyor (Stainless steel AISI 304) developed at CFTRI. In order to achieve uniform heating, the position of the samples, distance between the IR source and the material was fixed for all the trials. Maize flour (20 g) evenly spread (single layer) over a glass plate was exposed to IR at different combinations of temperature, time and initial moisture content.

2.2.3. Experimental design

A central composite design technique with three variables was used to study the response pattern to identify the optimum combination of variables for micronization of maize flour. The variables and their selected ranges were moisture content (20–40% wb), temperature (130–170 °C) and time (60–180 s) at five levels (Table 1) and six replications at the centre. Minitab statistical software 15.0 was used to analyse the data and to generate surface and contour plots. *In-vitro* starch digestibility measured as rapidly digestible starch (RDS) and peroxidase enzyme inactivation were the responses monitored. The following quadratic equation was used to build surfaces for variables.

$$Y = \beta_o + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_{ij} x_i x_j \quad (1)$$

where, Y = predicted response, β_o = a constant, β_i = linear coefficient, β_{ii} = squared coefficient, and β_{ij} = interaction coefficient.

Table 1
Experimental design with coded and uncoded values for the variables.

Factors	Levels				
Coded value	−1.682	−1	0	1	1.682
Temperature (X1)	130	138	150	162	170
Time (X2)	60	84	120	156	180
Moisture (X3)	20	24	30	36	40

2.2.4. In-vitro starch digestibility

In-vitro starch digestibility was carried out as per the method of Englyst et al. (1992) involving simulation of stomach and intestinal conditions and measuring glucose release at appropriate time intervals. The samples (100 mg) were subjected to enzyme hydrolysis for 20 min at 37 °C in a shaking water bath and at the end of 20 min of digestion, the samples were withdrawn and the amount of glucose released was determined and reported as rapidly digestible starch. Rapidly digestible starch is that portion of starch which is rapidly digested within the 20 min following incubation with enzymes. The starch digestibility index (SDI), a measure of relative rate of starch digestion of the test samples, was determined. Rapidly digestible starch content was calculated using the following equation.

$$\text{Glucose } (\%) = \frac{\text{At}_{20} \times \text{Vt} \times C \times D}{\text{As} \times \text{Wt}} \times 100 \quad (2)$$

$$\text{RDS} = (G_{20} - \text{FG}) \times 0.9 \quad (3)$$

where At_{20} is absorbance of the test sample after 20 min of incubation, Vt is the volume of test sample, C is concentration of the standard glucose, D refers to the dilution factor, As, absorbance of standard and Wt, weight of the sample and FG refers to free glucose.

2.2.5. Peroxidase enzyme activity

Maize flour (0.5 g) was extracted with sodium phosphate buffer (0.1 M, pH 6.7) over an ice bath for 1 h and centrifuged (8000 × *g*, 20 min, 7 °C); the supernatant obtained was used to determine peroxidase activity. The reaction mixture contained 0.2 mL enzyme extract, guaiacol as phenolic substrate and H_2O_2. The increase in absorbance was monitored spectrophotometrically at 470 nm for 5 min. One unit of enzyme activity is defined as the amount of enzyme that oxidizes guaiacol under standard assay conditions (Liu et al., 2013).

2.2.6. Carbohydrate, protein and fat content

Total carbohydrate was estimated by the anthrone reagent method (Sadasivam and Manickam, 2008). Crude protein content was determined by the Kjeldahl method (AOAC, 2000). Crude fat content was analysed as per the method outlined in AOAC (2000).

2.2.7. Total carotenoid analysis

Total carotenoid content was estimated as per the method of Rodriguez-Amaya (1999) with some modifications. Carotenoids from maize flour were extracted using water miscible solvent acetone until the residue becomes colourless, and the extract was filtered. The filtered acetone extract obtained was added to petroleum ether in a separating funnel and water was slowly added along the walls of the funnel to facilitate phase separation. The lower aqueous phase containing acetone was discarded and the