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Performance of Hot Air Puffing System for Corn

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A B S T R A C T

Maize is a coarse grain and accepted as staple diet and its demand is increasing year by year. The maize production of India in 2011-2012 is 21.5 million tones and the area under production is 7.18 million hectares and yield is 1959 kg/hectares. Research work is carried out on performance of hot air puffing system for corn. The continuous hot air puffing system can be set to any puffing temperature from 180 to 270°C and air velocity of 20 to 30 m/s. The performance of the developed machine was evaluated at different puffing temperatures (200°C, 220°C, 240°C and 260°C) and at different feed rate (50 g/min and 100 g/min). The optimum conditions for puffing of popped corn were found to be puffing temperature of 200°C and feed rate of 100 g/min. The puffing percentage and expansion ratio of popped corn were observed to reduce with increase in puffing temperature and feed rate the maximum puffing percentage and expansion ratio were found at 200°C as 86.51% and 13.36.

Introduction

Agriculture is one of the strongholds of the Indian economy and accounts for 18.5 per cent of the country's gross domestic product. Maize is a coarse grain and now it is being accepted as staple diet and its demand is increasing year by year. In India, maize is the third important cereal crop after rice and wheat in terms of area (Anonymous 2011). Currently, 49 per cent of maize output is used as poultry feed, 25 per cent as food, 13 per cent in starch and other industries, 12 per cent as animal feed, and 1 per cent as seed. Andhra Pradesh, Karnataka and Maharashtra are the major maize producing states. The value added products from maize which include maize starch, liquid glucose, dextrose monohydrate, anhydrous dextrose, sorbitol, corn gluten etc. During year of 2010-2011, maize was cultivated in 167 million hectares leading to a production of 860 million tones globally. The maize production of India in 2011-2012 is 21.5 million tones and the area under production is 7.18 million hectares and yield is 1959 kg/hectares. The market share of the Indian snacks is around US$ 3 billion (INR 137.4450 billion) with a growth rate of around 15-20 %. The unorganized snacks market is worth around US$ 1.56 billion (INR 71.4636 billion) with a 7-8 % growth rate. (Anonymous, 2011). The population of human being is ever increasing with vigorously changing lifestyle. This changing lifestyle is accompanied with changing demand, changing needs and habits. Major social, economic and demographic changes occurred over recent years have had great influence on the food we eat, and on where, when and how we do so. As a result, the convenience food sector has grown by 70% over the past decade, creating a huge market. Convenience foods are foods which designed to save consumers' time in the kitchen and reduce costs due to spoilage. These foods require minimum preparation, typically just heating, and can be packaged for a long shelf life with little loss of flavor and nutrients over time (Anonymous 2007).

The RTE foods are prepared by extraction, cooking, puffing, flaking, frying, toasting, roasting etc. While RTE food products include extruded snacks, puffed cereals, popcorn, rice-flakes, fried fryums, home-made products like 'papad', 'kurdai', 'chakali' which may be consumed after frying or roasting. The puffing process can broadly be classified as the sand puffing, salt puffing, air puffing, oil puffing and roller puffing as example of atmospheric pressure process (Chandrashekar and Chattopadhya, 1989) while gun puffing is example of pressure drop process (Hoseney, 1986). The oil puffing adds oil to the puffed products. The sand puffing imparts contamination of product with sand, while gun puffing demands extremely high working pressure. The extrusion puffing is highly sophisticated and required very high operating pressure and temperature. Puffing will ideally create an aerated, porous with added benefits of dehydration. Air-popped popcorn is naturally high in dietary fiber, low in calories and fat, and free of sugar and sodium. This can make it an attractive snack to people with dietary restrictions on the intake of calories, fat and/or sodium. Presently available technologies for whirling bed hot air puffing is accompanied with 'batch type' process. The batch requires to be put into process and then after puffing, it needs to be taken out. In order to ensure efficient batch processing, the LPG Gas system is provided for fast setting of required temperature and air velocity. The puffing in the 'batch' process and its removal on puffing, leads to increase energy requirement and process time per unit input. The emphasis will be made to put the raw product for puffing and to remove the final puffed product without disturbing the ongoing airflow rate and air temperature. The raw product should be put within whirling zone of hot air continuously and on puffing it should be taken out in continuous manner. To achieve the purpose of continuous input system and continuous removal of final product, some typical features need to be added in the present system. Besides to re-circulate the used air still having very high temperature is to be re-introduced in the heating zone. It will increase the thermal efficiency too and reduce total heat. There is a need to develop a new and continuous method for puffing corn seeds which could ensure control of temperature and the residence time. At the same time, it will turn out a product which will have more uniform quality and produced at much faster efficiency. Some researcher work on it and develop continuous hot air puffing system for different product, by considering all the point it is decided to develop hot air puffing system for corn. The present research work was therefore undertaken to evaluate the performance of developed hot air puffing system.

Materials and Methods

Selection of raw material

Corn kernels of variety "*VL Amber popcorn*" procured from local market were selected for present investigation. The typical composition of corn was endosperm 82.3%, germ 11.5%, bran 5.3% and tip cap 0.8%. The typical analysis of corn was moisture 9-15, starch 61%, protein content 8.5%, fibre 9.5%, oil 4 % and ash 1.6% dry basis

Performance evaluation of the developed hot air puffing system

The experimentation on hot air puffing of corn was conducted at required terminal velocity and by varying puffing air temperatures and feed rates as tabulated in Table 1, on the basis of preliminary experimentation.

The response parameters observed were puffing percentage (%), expansion ratio, hardness (g), crispness (number of +ve peaks) and sensory evaluation.

Puffing percentage

Puffing percentage is taken as percentage of puffed product (Np) out of total product in feed sample (N_t).

$$\text{Puffing percent} = \frac{N_p}{N_t} \times 100 \quad (5)$$

N_p = Number of puffed grains observed in sample,

N_t =Total number of grains in the sample

Expansion ratio

Expansion ratio is the ratio of volume of final product after puffing to the volume of raw product before puffing

$$\text{Expansion Ratio} = \frac{V_2}{V_1} \quad (6)$$

Hardness

Hardness is defined as the maximum peak force during the first compression cycle (first bite).

The hardness value depicts the texture perception of the consumer at first bite. It was measured using a Texture Analyzer.

Crispness

Crispness is related to the mechanical properties of the crust. Factors that determine these properties like the solid matrix i.e. starch properties, water content, crust structure, oil content.

Sensory evaluation

The sensory evaluation was done on the basis of numerical sensory card based on BIS: 6273 (Part II, 1971)

Results and Discussion

Performance evaluation of puffing machine

The system developed enables variation in puffing temperature from 180 to 270°C and air velocity from 20 to 30 m/s in puffing column.

Working of developed hot air puffing system

The air blower was switched on to allow the air circulation in system. Then heaters were switched on. Initial 6 heaters were switched on which was directly connected to contractor to heat the flowing air to 180-200°C temperature. Then remaining 3 heaters were put to ON, to increase the temperature to required levels for testing. It took 5 minutes for reaching temperature of 220°C. The temperatures of air in puffing chamber were varied by switching on the other heaters, one by one. The six numbers of switched heaters could achieve and stabilize air to temperature of 180 - 200°C temperature after 20 minutes. Sequentially next three heaters were switched, i.e. total nine numbers of heaters on switching could achieve temperature of 200–260°C in 35 minutes from start. Hence nine numbers of heaters were used and required temperature varied between 180 – 260°C. The air velocity at air inlet of puffing chamber was measured using digital anemometer without heating of air. The air velocity of air could be varied from 20-30 m/s using lever fixed on the periphery of blower. However the air velocity was fixed at 24 m/s in this study. The hot air puffing system for corn works on centrifugal air blower and electric heaters arranged typically in chamber. The air blower supplied air at atmospheric temperature (30°C), at the rate of 0.0912 to 0.136 m^3/s. This air was passed over series of electric heaters for heating from atmospheric temperature (30°C) to puffing temperature (180 to 260°C). It takes about 20 minutes for initial heating of air, to reach temperature of 180-200°C. This hot air was used for puffing in the puffing chamber. Once air was used, it was then recycled through re-circulating pipe (which was still hot and at about 170-180°C after being utilized) for further heating. The puffing chamber is vertical cylinder of diameter 76.2 mm, from the bottom of which hot air comes in typical manner. The product to be puffed was fed through the feed gate that works on positive feeding mechanism. The typical arrangement made to take, the puffed final product, out of the puffing chamber, carried the puffed material towards cyclone separator. The final product was taken out of the process from this cyclone separator and waste air (still hot at temperature of about 170-180°C) was again re-circulated for its reuse.

Experimentation for selection of appropriate process parameters

As discussed in section the experimentation with two variables i.e. puffing temperature as 200, 220, 240 and 260°C and feed rate of material as 50 and 100 g/min was conducted.

Effect of process parameters on various responses

The puffed samples were collected from bottom outlet of cyclone for each set of experimentation. These samples were evaluated for different response parameters like puffing percentage, PP (%); expansion ratio, ER; hardness, HD (g); crispness, CSP (number of +ve peaks) and sensory evaluation as discussed in following sections. The changes in responses with changes in experimental variables were analyzed using ANOVA.

Effect of puffing temperature and feed rate on puffing percentage

The effect of puffing temperature and feed rate on puffing percentage is shown in Figure 2. From the figure it could be seen that as the puffing temperature and feed rate is increased the puffing percentage is decreased. The maximum puffing percentage was found to be 86.51% for 200°C and 100 g/min feed rate.

Similarly the minimum puffing percentage was obtained as 79.056% for 260°C puffing temperature and 100 g/min feed rate. This may be due to the fact that the increased temperature causes burning of popcorn in a given residential time while increased feed rate decreased the chance of exposure of all corns to similar puffing conditions, may be due to increased crowding.

The standard statistical technique ‘Analysis of variance’ (ANOVA) was applied to study the effect of puffing temperature and feed rate on puffing percentage. Critical difference and co-efficient of variance (CV) were evaluated for puffing percentage puffing temperature and feed rate has significant effect on puffing percentage at 1% level of significance. However the interaction of these two variables is non-significant.

Effect of puffing temperature and feed rate on expansion ratio

The effect of puffing temperature and feed rate on expansion ratio is shown in Figure 3.

Table.1 Independent variables for optimization of process parameters for hot air puffing of corn

Sr. No.	Variables	Levels			
		1	**2**	**3**	**4**
1	Puffing air temperature, ^{o} C	200	220	240	260
2	Feed rate, g/min	50	100		-

Fig.2 Effect of puffing temperature and feed rate on puffing percentage (%)

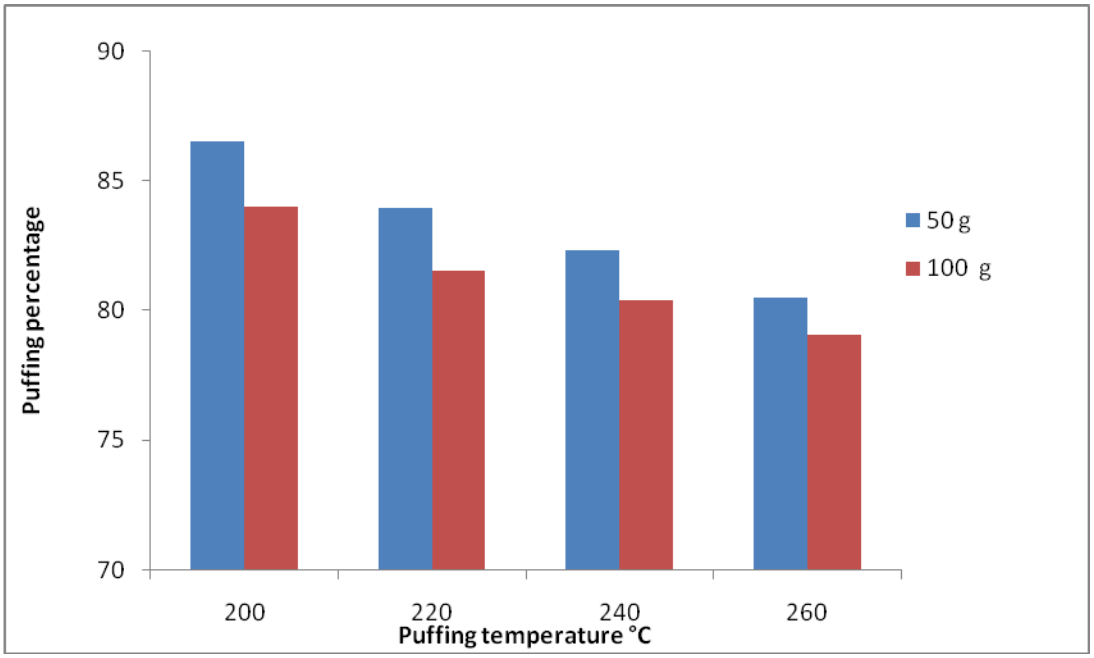


Fig.3 Effect of puffing temperature and feed rate on expansion ratio

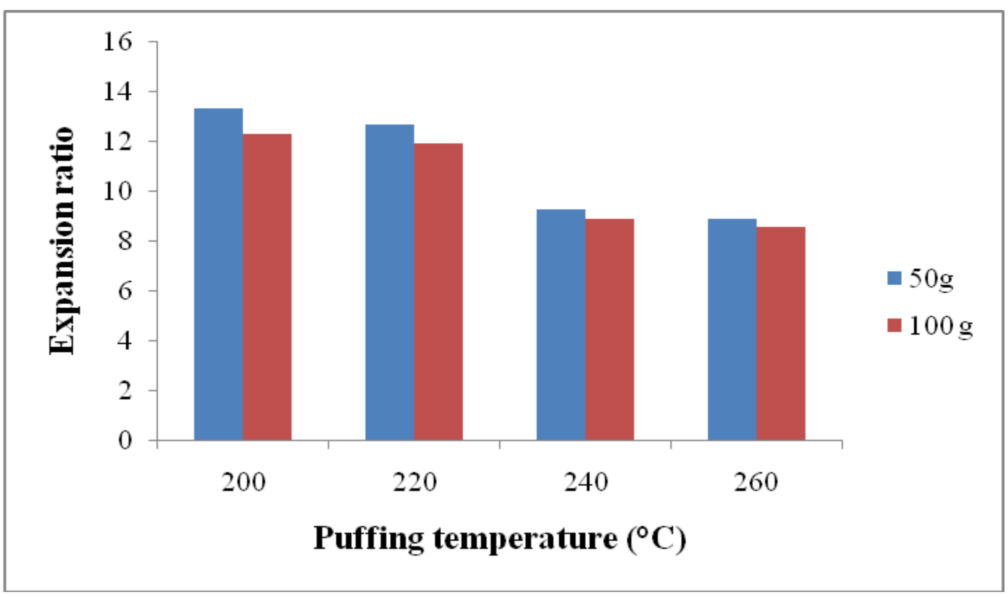


Fig.4 Effect of puffing temperature and feed rate on hardness

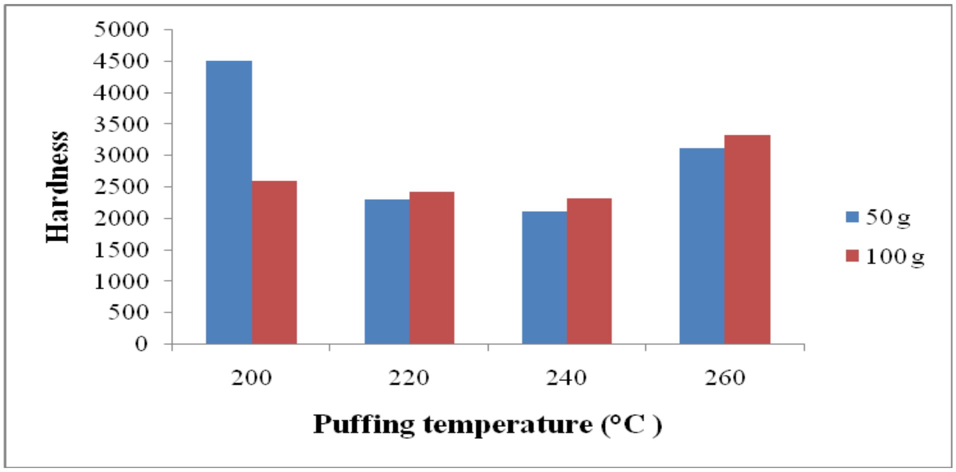


Fig.5 Effect of puffing temperature and feed rate on crispness

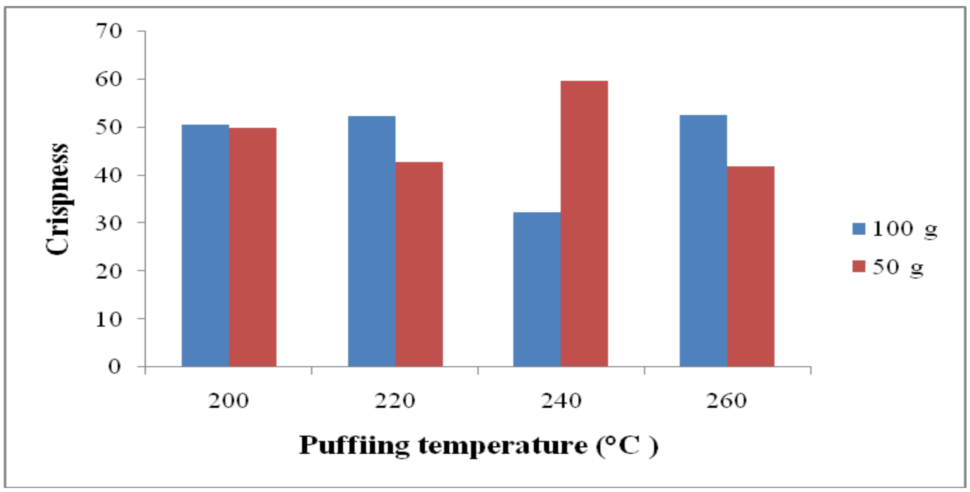
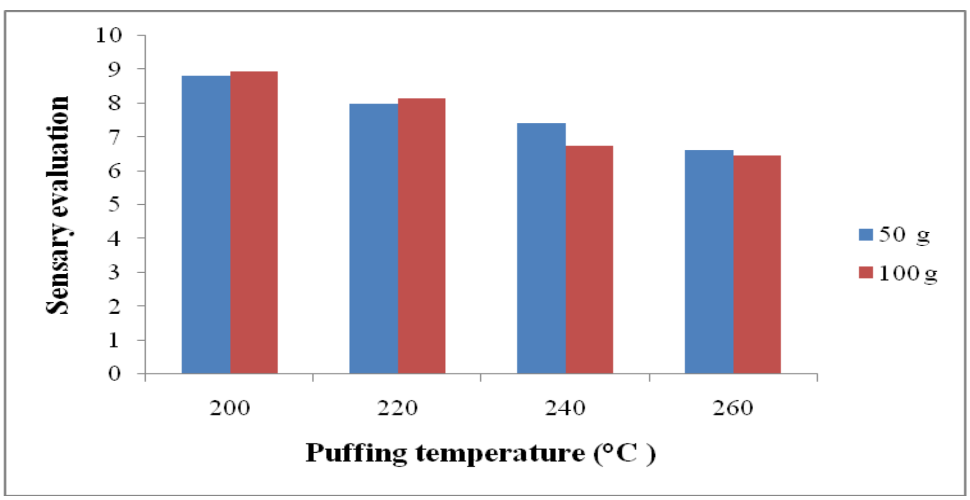


Fig.6 Effect of puffing temperature and feed rate on crispness



From the Fig. 3 it could be seen that as the puffing temperature and feed rate is increased the expansion ratio is decreased. The maximum expansion ratio was found to be 13.36 for 200°C and 50 g/min feed rate. Similarly the minimum puffing percentage was obtained as 8.58 for 260°C puffing temperature and 100 g/min feed rate. The decreased in expansion ratio with increased puffing temperature may be caused due to the fact that the increased temperature caused over heating of the product. The standard statistical technique 'Analysis of variance' (ANOVA) was applied to study the effect of puffing temperature and feed rate on expansion ratio. Critical difference and co-efficient of variance (CV) were evaluated for expansion ratio, puffing temperature and feed rate has significant effect on expansion ratio at 1% level of significance. However the interaction of these two variables has significant effect on expansion ratio at 5% level of significance.

Effect of puffing temperature and feed rate on hardness

The effect of puffing temperature and feed rate on hardness is shown in Fig. 4. From the Fig. 4 it could be seen that as the puffing temperature and feed rate is increased the hardness is decreased upto 240°C and increased thereafter with increase in puffing temperature. The maximum hardness was found to be 4508.33g for 200°C and 50 g/min feed rate. Similarly the minimum hardness was obtained as 2116.67 for 240°C puffing temperature and 50 g/min feed rate. This may be caused due to the fact that the increased temperature allowed more puffing, reduced moisture and thus reducing hardness while further increase in puffing temperature led to burning of the material, and thus increase in hardness. The standard statistical technique 'Analysis of variance' (ANOVA) was applied to study the effect of puffing temperature and feed rate on hardness. Critical difference and co-efficient of variance (CV) were evaluated for hardness, puffing temperature and feed rate has significant effect on hardness at 1% level of significance. The interaction of these two variables has significant effect on hardness at 1% level of significance.

Effect of puffing temperature and feed rate on crispness

The effect of puffing temperature and feed rate on crispness is shown in Fig. 5. There is no effect of puffing temperature and feed rate on crispness. The maximum crispness was found to be 59.7 for 240°C and 50 g/min feed rate. Similarly the minimum crispness was obtained as 32.3 for 240°C puffing temperature and 100 g/min feed rate. The standard statistical technique 'Analysis of variance' (ANOVA) was applied to study the effect of puffing temperature and feed rate on crispness. Critical difference and co-efficient of variance (CV) were evaluated for crispness puffing temperature has non-significant effect on crispness and feed rate has significant effect on crispness at 5% level of significance. The interaction of these two variables has significant effect on crispness at 1% level of significance.

Effect of puffing temperature and feed rate on sensory evaluation

The effect of puffing temperature and feed rate on sensory evaluation is shown in Fig. 7. From the Fig. 7 it could be seen that as the puffing temperature is increased the sensory scores is decreased. The maximum sensory scores was found to be 8.9 for 200°C and 100 g/min feed rate. Similarly the minimum sensory scores was obtained as 6.5 for 260°C puffing temperature and 100 g/min feed rate. This may be due to the fact that increased puffing temperature might have caused burning of the product led to brown colour.

The standard statistical technique 'Analysis of variance' (ANOVA) was applied to study the effect of puffing temperature and feed rate on sensory evaluation. Critical difference and co-efficient of variance (CV) were evaluated for sensory evaluation puffing temperature has non-significant effect on sensory evaluation and feed rate has significant effect on sensory evaluation at 1% level of significance. The interaction of these two variables has non-significant effect on sensory evaluation

The continuous hot air puffing system enables continuous feeding of raw material and continuous exit of puffed product, hence frequent resetting of temperatures and air velocities is not required. The continuous hot air puffing system reduced requirement of energy due to recirculation of used but still hot air. The fifty percentage heat load was reduced which reduced the processing cost of hot air puffed corn. The continuous hot air puffing system can be set to any puffing temperature from 175 to 300 °C and air velocity of 20 to 30 m/s. The optimum conditions for puffing of corns were found to be puffing temperature of 200 °C and feed rate of 100 g/min, i.e. 6 kg/h.

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