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Jitendra Kumar
Mandan Bharti College of Agriculture, Saharsa, Bihar, India

Satish Kumar
Bihar Agricultural College, Sabour, Bhagalpur, Bihar, India

Ashok Kumar
Bihar Agricultural College, Sabour, Bhagalpur, Bihar, India

Sanoj Kumar
Bihar Agricultural College, Sabour, Bhagalpur, Bihar, India

Corresponding Author:
Satish Kumar
Bihar Agricultural College, Sabour, Bhagalpur, Bihar, India

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Field performance of popping machine for Makhana seeds

Jitendra Kumar, Satish Kumar, Ashok Kumar and Sanoj Kumar

Abstract
North Bihar is a major producer of makhana (*Euryale ferox*), the main indigenous aquatic cash crop of Mithila region of Bihar (India). A prototype Makhana popping machine was developed to address the basic constraints and drudgery involved in Makhana processing, increase the processing capacity, minimize processing time, remove the drudgery of the operations involved as well as to improve the quality of popped makhana. The machine could have two units: a preheater-cum-roaster unit and an Impacter unit for popping. The popped makhana and the shell were collected from the discharge outlet of the makhana popping machine and separated. The yield of makhana, popping efficiency and recovery of grade I makhana were determined. The effect of impeller speed on grade-I makhana was negligible. The performance of the newly developed makhana popping machine was found satisfactory at 10 kg/h feed rate and impeller speed of 2600 rpm. A profit of Rs.9.25 per kg is obtained by using this machine. The currently available technology of Makhana processing is not only indigenous and manual but also cumbersome and painstaking. The process involves handling of hot roasted seeds which require two to three labourers to process 8-9 kg of popped Makhana per day. With the view to mechanize the unit operation involved in Makhana processing, grading and roasting machine were designed and developed. Grader was developed based on engineering properties of Makhana while the roaster was designed based on preliminary experiments for Makhana, i.e. shell breaking force at different temperatures and for varying residence time. The developed roasting machine worked satisfactorily with 80-85% popping efficiency at machine capacity around 10 kg/h.

Keywords: Makhana, popping, impeller speed, pre-heater, popping efficiency, feed rate

Introduction
Makhana (*Euryale ferox*) is an important aquatic crop, but is still neglected, probably because of lack of awareness among the rural masses in other parts of India than Bihar. In India, there are a lot of fallow wetlands, which remain unutilized round the year. In such case, Makhana cultivation may fetch more revenue to the poor masses. It only requires sincere efforts including dissemination of traditional knowledge as well as awareness to cultivate Makhana – a unique food resource.

Makhana is a main support for livelihood of the poor people. Makhana cultivated water bodies are also utilized along with fish culture. It is a perennial aquatic floating leaved herb, cultivated as a seasonal annual crop, which dies out after the fruits mature. The plant grows in fallow wetlands of standing shallow water of about 2.5 m depth and has rhizomatous stem. It was once distributed in India, covering a long range from Kashmir to Manipur alongside the Himalayan stretch from Northwest to Far East. Now, its distribution has been confined within Bihar, along with adjacent states like Orissa, West Bengal, and Assam. It prefers tropical and sub-tropical climate, temperature between 20 °C - 35 °C, humidity between 50 percent - 90 percent and rainfall between 100 cm - 250 cm. Makhana is either eaten as raw puff or blended with vegetables, dal, etc. The seeds are edible after being processed and highly nutritious. It falls under one of the superior food qualities, which is reflected in its high amino acid index (89% - 93%) and arginine lysine/proline ratio (4.74-7.6). Caloric value (3.62 kcal/gm) is also remarkable as compared to staple foods. It has a prominent place in Indian dietary chart with medicinal values for respiratory, circulatory, digestive, renal and reproductive diseases. Commercially it is grown in Mithilanchal districts of Bihar comprising areas of Madhubani and Darbhanga. These areas accounts for 90 percent of estimated 75,000 tons of country's total annual production of makhana.

The economic part of makhana is the popped expanded kernel which is used as a delicious food. The edible part of the nut is its starchy kernel which cannot be separated easily from the raw nut. It is therefore popped, manually by the traditional methods (Jha and Prasad 1990) as there is a lack of scientific methods of popping. Popping is the process of creating superheated water vapour within the conditioned nut by heating the contained moisture, and suddenly releasing the pressure to cause a volumetric expansion of the kernel. The expanded kernel of the nut obtained through this process is known as makhana in India (Jha and Prasad 1998). Due to low fat content, high content of carbohydrate, protein and minerals, it is one of the most common dry fruits utilized by the people. The calorific value of raw seeds (362 kcal/100g) and puffed seeds (328 kcal/100g) lie close to staple foods like wheat, rice, other cereals (Bilgrami *et al*. 1983) [1]. Besides nutritional value makhana is also recommended in the Indian and Chinese system of medicine in the treatment of respiratory, circulatory, digestive, excretory and reproductive systems disorder.

Considering the fact in delay and time taking during traditional roasting, a Makhana Popping Machine has been developed under non-plan project entitled "Development and Processing of Makhana Popping Machine".

Materials and Methods

Sample preparation

For design and development of makhana popping machine first we have studied the physico-chemical and engineering properties of Makhana, Raw material was procured from local market of Saharsa and Purnea. The experiment was conducted in Agricultural Engineering department at Bihar Agricultural College, Sabour and Mandan Bharti Agriculture College, Saharasa. One lot of 2 kg of sample was cleaned, washed and graded according to average diameter and sphericity. Then Makhana popping Machine has been fabricated at Mandan Bharti Agriculture College, Agwanpur (Saharsa) and the machine parameter as well process were optimized for the popping of makhana seeds.

Proximate/Chemical analysis of makhana seeds

The proximate analysis gives useful information about the material, particularly from nutritional and bio-chemical point of view. Following proximate constituents were analyzed.

1. Initial Moisture content

The moisture content of raw and popped makhana seeds was determined by standard oven drying method. About 10g of representative sample was weighed and kept in oven at 105±2 ^{O}C for 24 hours. The dried samples were cooled in desicator to room temperature and then weighed using electronic balance and the moisture content of the material was expressed in wet and dry basis (Ranganna, 2002) [8].

2. Ash content

The ash content of a foodstuff or cereal grain represents inorganic residue remaining after destruction of organic matter. It may not necessarily be exactly equivalent to the mineral matter as some losses may occur due to volatilization. Taking tare weight of three silica dishes (7-8 cm dia.). Weigh 2 gm of sample into each. Now ignite the dish and the contents on a Bunsen burner. Ash the material at not more than 525 ^{0}C for 4 to 6 hrs. Now cool the dishes and weigh. The difference in the weights gives the total ash content and is represented as percentage.

3. Fat content

Fat soluble material in a food or cereal is extracted from an oven dried sample using a soxhlet extraction apparatus**.** The ether is evaporated and the residue weighed. The ether extract or crude fat of a food represents, besides the true fat (triglycerides), other materials such as phospholipids, sterols, essential oils, fat soluble pigments, etc. extractable with ether. Water-soluble materials are not extracted since the sample has been thoroughly dried prior to extraction with anhydrous ether.

$$(\%)\text{Fat} = \frac{\text{Wt.of the fat soluble material}}{\text{Wt.of the sample}} \times 100 \quad (7)$$

4. Protein content

Determination of protein content or Nitrogen content is estimated by Kjeldahl method which is based on the determination of the amount of reduced nitrogen (NH_2 and NH) present in the sample. The various nitrogenous compounds are converted into ammonium sulphate by boiling with conc. H_2SO_4. The ammonium sulphate formed is decomposed with an alkali (NaOH), and the ammonia liberated is absorbed in excess of neutral boric acid solution and titrated with standard acid.

$$N_2\,(\%) = \frac{(\text{sample titre - blank titre}) \times \text{N of HCl} \times 14 \times \text{vol. made up} \times 100}{(\text{Aliqout}) \times \text{Wt. of the sample taken} \times 1000}$$

$$\text{Protein}\,(\%) = N_2\,(\%) \times 6.25 \quad (8)$$

5. Crude fibre content

Crude fibre consists largely of cellulose lignin (97%) plus some mineral matter. It represents only 60-80% of the cellulose and 4-6% of lignin. Commonly used in quality & quantity. Extract 2g of ground material with ether to remove fat (Initial Boiling temp. 35.38 ^{0}C and final temp. 52 ^{0}C). After extraction with ether boil 2g of dried material with 200 ml of H_2SO_4 for 30 min. with bumping chips. Then filter through muslin and wash with boiling water until washing are no longer acidic. Then boil with 200 ml of NaOH solution for 30 min. Filter through muslin cloth and wash with 25 ml of boiling 1.25% H_2SO_4 3.25 ml portion of H_2O and 25 ml OH. Remove the residue and transfer to ashing dish (w_1). Drying the residue for 2 hour at 130 ^{0}C. Cool the dish in desicator and weigh (w_2) and ignite it for 30 min. at 600 ^{0}C then cool in a desicator and weigh (w_3).

$$(\%)\ \text{Crude Fibre} = \frac{\{(w2 - w1) - (w3 - w1)\}}{\text{Wt.of the sample}} \times 100 \quad (9)$$

Roasting chamber **Power Control Unit** **Heating chamber**

Motor Attach Frame **Makhana Popping Chamber** **Impeller**

Fig 1: Different components of makhana popping machine

Results and Discussions

Physical/Engineering properties of makhana seeds

Physical and engineering properties of makhana seeds have been evaluated for the purpose of designing suitable equipment for the makhana popping machine. Since, popping of makhana seeds is not a continuous process, so before popping makhana seeds is cleaned and washed then, seeds is dried for the storage at a suitable moisture content and then it is graded before first and second roasting. Then finally popping occurs after second roasting then grading and separation of popped kernels occurs before packaging and marketing. Table 1 shows all the physical properties of makhana seeds, which was calculated samples for 100 observation and tabulated. Whereas Table 2 and 3 shows the engineering properties of raw makhana seeds and these values was good acceptable for designing of makhana popping machine.

Table 1: Physical properties of makhana seeds

Physical property	Number of observations	Mean Value
Length, mm	100	12.40
Width, mm	100	12.10
Thickness, mm	100	11.73
Geometrical mean diameter, mm	100	12.10
Sphericity,	100	0.917
True density, Kg/m^3	100	1155.00
Bulk density, Kg/m^3	100	637.80
Porosity, %	100	44.78
Seed Weight, g	100	0.675

Table 2: Angle of Repose and Hardness of Makhana seeds at different stages

Treatment	Moisture content, (% d.b)	Angle of repose, degree	Hardness (N/mm^2)
Raw Makhana	60.00	22.10	402.10
Dried Makhana	33.00	21.70	471.50
Pre heated Makhana	25.74	21.40	567.16
Roasted Makhana	11.50	21.10	683.59

Table 3: Co-efficient of friction of Makhana Seeds (25.74%, d.b)

Components	External friction
Sun mica sheet	0.11
Copper sheet	0.11
Mild Sheet	0.12
Aluminum sheet	0.14
Canvas Sheet	0.15
Wooden play sheet	0.16
Asbestos cement sheet	0.17
Internal Friction (Seed to Seed)	0.17

Chemical/Proximate composition of makhana seeds

Three samples of makhana were procured from the local market to study their proximate composition. Small variations were observed in the different parameters analyzed. These may be due to environmental differences like soil, water, and air.

Table 4: Proximate composition of raw makhana seeds

Raw makhana	M.C (%, w.b)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Crude fibre (%)
Sample A	10.80	10.54	0.392	3.424	72.37	2.47
Sample B	11.75	11.12	0.418	3.416	70.84	2.46
Sample C	09.94	10.24	0.408	3.394	73.48	2.54

Moisture content was found lowest in sample C which may be due to the variation in environmental conditions and cultivation practices. Protein content in makhana ranged between 10.24 to 11.12 percent. The estimated content was found to be lower than reported earlier. The fat content of all the three samples were comparable to each other. In the present study, a fat content of 0.4 percent was observed; while the reported values were quite lower (0.1 percent). Approximately, 3.4 percent total ash content was observed in the three makhana samples. Makhana contained a good amount of fibre content (2.46 to 2.54 percent).

Table 5: Specification of Developed Makhana Popping Machine

Sl. No.	Parts of machine	Specification
1	Size of Impeller	480 mm
2	Motor capacity	2HP of Single phase
3	Size of Popping Chamber	610 × 385 mm
4	No of heaters	13 (each having capacity of 500 Watt)
5	Blower motor size	0.5 HP
6	Temperature inside roasting chamber	230-310 ^{O}C

Results on machine performance

Table 6: Machine performance for feed rate 200 makhana seeds

Run	Impeller speed (RPM)	Popping efficiency %			Recovery of makhana kernel %			Broken kernel %			Unshelled of makhana seed %		
		230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C
1	1800	65	70	73	61	65	66	4	5	7	35	30	27
2	2000	70	74	77	65	68	69	5	6	8	30	26	23
3	2200	71	75	78	68	72	73	3	3	5	29	25	22
4	2400	76	80	81	72	75	74	4	5	7	24	20	19
5	2600	78	82	83	75	78	77	3	4	6	22	18	17
6	2800	77	82	83	72	74	72	5	6	11	23	18	17

Table 7: Machine performance for feed Rate 250 makhana seeds

Run	Impeller speed (RPM)	Popping efficiency %			Recovery of makhana kernel %			Broken kernel %			Unshelled of makhana seed %		
		230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C
1	1800	62	64	74	58	60	67	3	4	7	38	36	26
2	2000	66	67	78	62	63	70	4	4	8	34	33	22
3	2200	67	68	79	64	65	71	3	3	8	33	32	21
4	2400	72	74	81	68	70	72	4	4	9	28	26	19
5	2600	73	74	83	70	71	73	3	3	10	27	26	17
6	2800	71	73	82	67	69	71	4	4	11	29	27	18

Table 8: Machine Performance for Feed Rate 300 Makhana seeds

Run	Impeller speed (RPM)	Popping efficiency %			Recovery of makhana kernel %			Broken kernel %			Unshelled of makhana seed %		
		230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C	230 ^{O}C	250 ^{O}C	280 ^{O}C
1	1800	60	61	72	57	56	67	3	5	5	40	39	28
2	2000	64	64	75	60	60	69	4	4	6	36	36	25
3	2200	65	65	76	63	62	70	2	3	6	35	35	24
4	2400	69	70	79	66	65	72	3	5	7	31	30	21
5	2600	71	71	80	68	68	72	3	3	8	29	29	20
6	2800	70	70	79	66	66	70	4	4	9	30	30	21

Fig 2: Makhana popping machine

Fig 3: Machine output

Conclusion

A popping machine has been developed at Mandan Bharti Agriculture College, Agwanpur (Saharsa) for the makhana seeds. The performance of the newly developed makhana popping machine was found satisfactory at 10 kg/h feed rate and impeller speed of 2600 rpm. A profit of Rs.9.25 per kg is obtained by using this machine. The currently available technology of Makhana processing is not only indigenous and manual but also cumbersome and painstaking. The process involves handling of hot roasted seeds which require two to three labourers to process 8-9 kg of popped Makhana per day.

With the view to mechanize the unit operation involved in Makhana processing, grading and roasting machine were designed and developed. Grader was developed based on engineering properties of Makhana while the roaster was designed based on preliminary experiments for Makhana, i.e. shell breaking force at different temperatures and for varying residence time. The developed roasting machine worked satisfactorily with 80-85% popping efficiency at machine capacity around 10 kg/h.

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