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Original Research Article

Optimization of traditional puffing of a nutritious local grain (*Amaranthus spp.*) and development of a scalable business model supporting community health

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ABSTRACT

Background: Promoting and encouraging use of diverse nutritious grains is not only healthy but can also, provide livelihood opportunities to rural groups.

Aim: The study attempted a farm to table approach by standardizing traditional puffing of amaranth grains and training women for a batch scale process to develop a scalable business model.

Materials and Methods: Manual puffing process for amaranth grains was developed and standardized. Puffed samples were compared with market samples for sensory parameters, expansion ratio, nutritive composition and sodium content using SPSS and MS-excel statistical analysis.

Results: It was observed that direct heat puffing of cleaned and sieved grains on inclined karahis, provided good puffing efficiency (approximate 94%). Manually puffed grains had similar nutritional values and were crunchier than the market samples. Though, the machine puffed samples had better expansion ratio but, a higher sodium content of 1349.01 ± 0.073 and 1346.15 ± 0.014 mg/100g was reported when compared with manually puffed grains having only 135.3 ±0.037mg/100g of sodium. Individual capacities of women were observed for six months to develop a learning curve to understand production efficiencies. The production capacity of women ranged from 2250 kg to 3250 kg per month. A traceable model was developed, by procuring grains from small and marginal farmers, and processing undertaken by trained women groups.

Conclusion: A production of 34, 936 kg of puffed grain in the FY 2020-21 indicated a potential for a sustainable business supporting livelihoods and health.

1. Introduction

The need for healthier diets has opened new grounds for food biodiversity. Apart from understanding the ingredients that meet diverse culture, taste preferences, nutrient mix, the availability and accessibility of such crops is also being explored through agrobiodiversity. According to the FAO statistical yearbook report for food and agriculture, 2020 four crops namely, sugarcane, maize, wheat and rice account for 50% of the global primary crop production.[1] No doubt, this reliance on a few grains will raise serious concern for future agricultural sustainability and vulnerability. To address nutritional and food security challenges with environment sustainable agriculture systems, traditional grains having resilience to environmental conditions are being ploughed back into the food system. One such crop, that is found to be promising is Amaranth.

Amaranth grain has been in use since ancient times. It also has been an important part of the staple diets of Mesoamericans, Aztecs.[2] Reviews have suggested that in the cultivated regions of amaranth, people use amaranth leaves as vegetable and grains as flour in bakery preparations such as cookies, biscuits, candies, pancakes, pasta, and noodles.[3–5] In India, people in the Himalayan region use this grain flour to prepare chapattis/Indian breads,

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and also as sattu.[2]

Amaranthus, in India, is majorly grown in the Himalayas and to some extent in the states of Gujarat, Maharashtra, Karnataka and eastern parts of Uttar Pradesh and is used as an important staple in these regions during the season.[6,7] The grain is known by various nomenclature as *Raj gira*, *Ram dana* or *chulai* and is used to make laddoos and other snacks to be consumed during the fasting days. The yield of Amaranthus seeds is highly variable and depends upon many factors such as soil condition, species, fertilizer input, geographical location etc. In northern parts of India, along the Himalayan belt, the crop is sown at the onset of monsoon (mid- June) and harvested in October but in west and southern part, it may be grown throughout the year. The grain yield ranges from 0.5 tons per hectare to 2.5 tons per hectare on dry-weight basis.[8] According to Uttarakhand Organic Commodity Board (UOCB), amaranth is mostly cultivated in Uttarkashi, Rudraprayag, Tehri, Almora, Pauri and Bageshwar districts.[9] It is a fast-growing crop (takes around 90-160 days) and is adaptable to a wide range of soils and climates.[2] In view of its tolerance to major abiotic stresses, amaranth has now emerged as a major climate resilient nutritious crop.[2,10,11] Studies have shown that the water requirement for growing amaranth is 53–58% less than that required for wheat; 40–50% less than maize; and 21% less than cotton.[8,12]

Amaranth grain is also known for its high nutritional properties. Absence of gluten makes it even more preferred by nutritionists as it is ideal for celiac intolerant people.[13–15] Unlike other cereal crops, the lysine content of amaranth is twice and thrice as much as rice and corn, respectively.[16,17] Amaranth has been regarded as super food owing to its phytoconstituents, macronutrients and minerals composition, dietary fibre and antioxidants.[18–20] The higher levels of protein and fat present in the seeds are attributed to the higher percentage of bran fraction when compared to the common cereals.[21] It has also been proven in a study that bread made from amaranth cereal had beneficial effects on the haemoglobin concentration, thus can aid in preventing anaemia prevalence.[22]

These days consumers are inclined towards healthy ready-to-eat snacks. Popping/puffing is one such technique to consume healthier grains with increased digestibility. In the popping process, the kernels are heated until the interior moisture expands and pops out through the outer shell of the kernel.[23] Popping or grain puffing also helps to impart desirable flavour and aroma to the grains.[24] Studies have also reported that during puffing of amaranth grain, nutrition is kept intact for protein, starch, fat and fibre but not for tocopherol which reduces due to heat treatment.[25,26] No doubt, puffing needs careful processing as the smaller grains tend to burn and scratch.[24]

This study attempted to standardize the process for manual puffing of amaranth grain as a livelihood approach for better community health. The study had following objectives:

1. Identification of supply of amaranth from small and marginal farmers.
2. Standardization of manual puffing process for a batch scale production.
3. Training of women group for production of puffed grain for the market.
4. Preparation of a decentralized model of production with quality process controls.

2. Materials and Methods

2.1. *Sourcing of grain*

Raw amaranth grains were sourced from district Almora, Uttarakashi (Uttarakhand) through a farmer collective group. The members of the collective were engaged with small and marginal farmers and collected the produce for better bargaining power.

2.2. *Optimization of the puffing process*

Process of optimization started with grain selection, cleaning and sieving. Puffing method, time, puffing efficiency were studied during puffing process for a batch scale manual production. Grains were puffed traditionally by open pan method at 230°C ± 10°C with constant stirring. For this purpose, Karahis of 25 kg capacity, having 26 inches diameter and 8-inch depth were used. The process was studied for various methods such as puffing with sand, salt, with or without moisture to test the feasibility for a batch scale production. Puffing efficiency, expansion ratios and sensory attributes were studied and compared with the machine puffed market samples.

2.2.1. *Puffing efficiency*

The puffing efficiency depends upon quality, maturity and moisture content in the grain.[27] Therefore, puffing efficiency was measured for different samples of grains sourced at different times and variations in the moisture content studied.

Puffing efficiency was calculated as:

$$\frac{Weight\ of\ puffed\ sample}{Weight\ of\ raw\ grains} \times 100$$

2.2.2. *Expansion ratio*

Expansion ratio of any puffed grain tells us the degree of expansion and is an important parameter for market sales.[23,27–28] Volume was measured before and after puffing of grains by filling a known weight in a graduated measuring cylinder and volume was noted after tapping.

The expansion ratio was calculated as-

$$\frac{Total\ popped\ volume\ (ml)}{Volume\ of\ raw\ kernels\ (ml)}$$

2.2.3. Sensory analysis

The sensory attributes of the market puffed grains and traditionally puffed grains were compared based on their crunchiness and appearance. The sensory analysis was done by a group of 60 semi and untrained panellists on a five-point hedonic scale. The sensory analysis and expansion ratios of the manually puffed and market products were analysed and the difference was studied through Duncan test run in SPSS software.

2.3. Nutritive value

The nutrient composition of prepared samples and market samples was analysed. A comparison was also made for the sodium content. The market puffed samples were marked as Sample A and B, and our traditionally manual puffed amaranth was marked as Sample C. Standard analytical methods were followed for the estimation of Moisture, Protein, Carbohydrate, Fat, Dietary fibre and Sodium (AOAC methods, 2005).[28]

2.4. Statistical analysis

All the values for different tests were done using triplicates. The statistical analysis was carried out using Microsoft excel and SPSS software to determine the significant difference, mean and standard deviations. Duncan's test was applied for comparing the average sensory scores and expansion ratios of the puffed sample with market puffed products.

2.5. Development of a production pilot

After the successful manual puffing trials, the process was scaled up to the industrial level with all process controls. For the development of a sustainable batch scale decentralized model, following tools were adopted:

1. Knowledge sharing and training
2. Learning curve.
3. Process optimization through development of SOPs and controls.

2.6. Period of study

September 2019 to March 2021.

3. Results

Amaranth grains were sourced from Almora district in Uttarakhand. Agriculture here, is mainly rainfed and seeds are planted in the month of June and the crop is harvested in October. The cropping system, in the region involved intercropping of five or more crops namely, ragi, red rice, pulses, kulthi, sarso and vegetables and no pesticides or chemicals were used. Almost 70% of the women were involved in the faming processes. The produce after harvest was sundried, cleaned and then kept in Kothars (traditional storage structures in the villages). Aggregators collected the produce systematically and as per demand and stored them for dispatch (Figure 1).

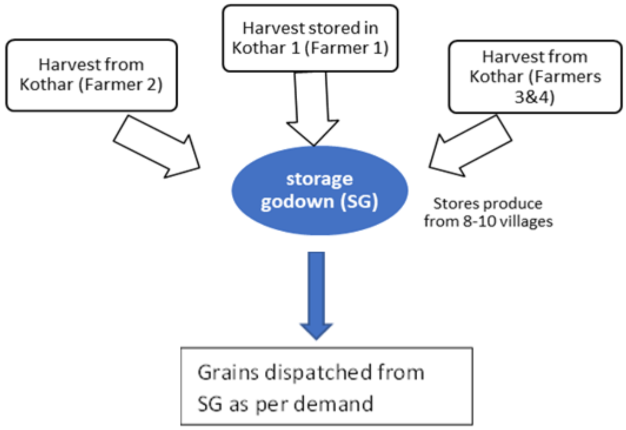

Fig. 1: Supply of Amaranth grain from collectors

3.1. Post-harvest handling of the grains

During the project tenure, several trainings were provided to the farmers and aggregator group for cleaning, sorting, weighing, packing and batch number coding for produce traceability. These trainings were conducted in small groups in the villages as well as in godowns (Figure 2 a,b).

Fig. 2: a: Small group training session at village; **b:** Process training for post-harvest handling

3.2. Sample preparation for puffing trials

The sourced amaranth grains were cleaned using sieves to separate all foreign matter, dirt, twigs, broken and immature grains.

3.3. Manual puffing – Process optimization

The manual process was selected for the puffing since it was less capital intensive and could be easily adopted in a decentralized processing operation. The puffing trials were conducted in open karahis that ensured minimal processing of the grain. The process was optimized for the temperature, time, quantity and puffing quality. Parameters as expansion volume and sensory scores were tested in comparison to the machine puffed market samples.

For the basis of quantity measurement, standard measuring cup was used to pour grain for puffing into the karahi. It was observed that one full cup of amaranth gave 100 ± 5g weight of raw amaranth grains. Therefore, the roasting trials were done using 1,2,4 and 5 cups of amaranth grains corresponding to 100, 200, 400 and 500 g, respectively (Table 1).

Various puffing conditions were tried to understand effect on quality and yield. As per the literature review, various methods for grain puffing were tried out - puffing after hydration and conditioning of the grain, puffing with sand, puffing with salt as a medium, puffing without any pre-treatment and by direct puffing. All the four methods were tried out to check the feasibility of the process and puffed grain quality. For the hydration, 150g of grains were sprinkled with 10 ml of water and this was made to rest for 3.5h. These grains were heated on low flame to achieve equilibrium after which puffing operation was performed. For salt and sand puffing, 25g of salt and sand were used respectively and heated to 250±10°C The grains were then puffed in the respective medium, puffed with continuous stirring. The puffed samples from all the four methods were studied for puffing time, percentage of puffing and OAA values (overall average acceptability score values) based on their taste and crunchiness (Table 2).

Puffing efficiencies were calculated for grains procured at different times of the year represented as sample A, B, C, D, E, F. These were studied to check the seasonal variations if any, on the puffing efficiency. The puffing efficiency was compared with the moisture content of the grains.

Manually puffed amaranth grains and market puffed grains were compared for sensory attributes, expansion ratio and nutritive values (Table 4). Duncan test was run on the sensory scores and expansion ratios to estimate the significance difference amongst the samples.

3.4. Scaling up for production process

The manual process after successful trials was subjected to a production process. The women group was trained for various skill process involved in the entire operation. Since puffing was a critical process to achieve production efficiencies, ladies trained for this process were studied for skill efficiency through the help of a learning curve (Figure 3).

After the entire process was tried for a batch scale process, it was put in operation as per the process controls for the Standard Operating Process (SOP) prepared to achieve the final product of puffed grain for market sale

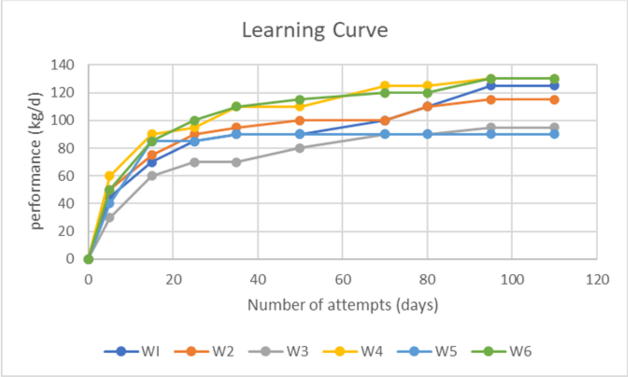

Fig. 3: Learning curve for skill efficiencies

(Figure 4). The packaging was optimized with sealing in two bags (inner LDPE and outer laminated Gunny bag). A total of 34, 936 kg of puffed grain was produced during FY 20-21 under this model.

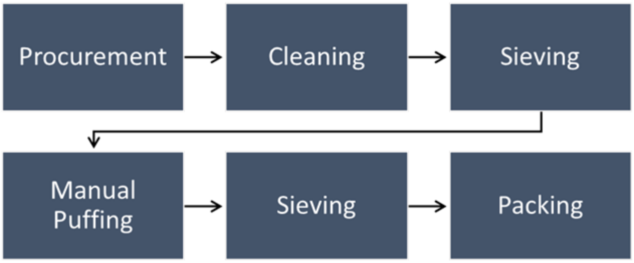

Fig. 4: Flow chart of the standardized manual process for puffing of amaranth grain

4. Discussions

During the temperature trials for puffing, it was observed that the amaranth grains started puffing at 195 ±10°C but gave lower efficiencies of around 70%. Therefore, puffing was tried at higher temperature and it was noted that at 230±10°C better puffing efficiencies could be achieved. This has also been reported by Mandhare et al[29] in 2020, in which it was observed that the percentage of puffing quinoa grains was only 59% at 200°C but 80% at 240° C, 87% at 260°C, which then decreased to 82% on increasing the temperature further.[29] According to Subramani D et al 2020, puffing yield gets increased with an increase in puffing temperature and puffing time because of the increment in vapour pressure inside the grain leading to the puffing of the maximum number of grains.[27]

It was also observed that when the karahis were inclined, it helped in aiding the emptying process of the puffed grains, thereby increasing the efficiency of the entire process. The chullahs were constructed so as to obtain the inclination of 30° in the heating vessel and also took care of the ergonomic conditions for the ladies to handle the puffing operation

Table 1: Standard measure of the grain sample for manual puffing process

Sample weight (g)	Puffing Time (s)	Puffed (%)	Burnt (%)	Time of emptying out (sec)	Observations
500	64.67±0.58	85.67±0.58	8.54	8-10	Loss of grains during constant stirring process while puffing. Also, burning observed as puffing was difficult to handle with constant stirring
400	57.33±0.58	86.6±0.79	5.52	6-7	Little burning observed during emptying out
200	43.67±0.58	94.17±0.25	Nil	4-5	Overheating observed while taking out the product
100	32.33±0.58	94.57±0.06	Nil	3-4	Ease of proper emptying out led to an efficient operation

Table 2: Traditional puffing method trials for the batch process

Condition	Time of puffing (s)	Percentage puffed	OAA
Direct puffing of the grains without any pre-treatment	32	93.61±0.01	4.25±0.50
Pre- treatment of grains with hydration	56	85.03±0.15	3.1 ±0.58
Grains puffed with salt as medium	30	94.07±0.06	3.25 ± 0.50
Grains puffed with sand as medium	35	94.19±0.12	2.5 ± 0.58

Table 3: Samples procured at various times during a span of 8 months from the villages tested for puffing efficiency

S.No	Samples procured at various times from the village	Puffing efficiency (%)	Moisture of sample grains taken for puffing
1	A	93.45%	10.87±0.046
2		92.53%	11.10±0.015
3	C	84.30%	12.95±0.030
4	D	89.98%	11.57±0.021
5	E	85.67%	12.37±0.012
6	F	82.60%	13.91±0.015

Table 4: Comparison of market and manually puffed grains for puffing characteristics and nutritive value

Evaluation Criteria	Parameter	Market Sample A	Market Sample B	Manually puffed sample C	F value
Sensory Analysis	Appearance/Colour	4.43±0.4997a	4.23±0.4997b	3.85±0.3601c	25.142
	Lightness	4.38±0.5237a	4.30±0.4621a	3.72±0.4544b	34.205
	Crunchiness	2.08±0.4618b	2.13±0.3428b	4.13±0.4682a	447.545
	Taste	3.80±0.4034b	3.73±0.4460b	4.15±0.3600a	18.335
	Overall acceptability	4.27±0.5480ab	4.22±0.4540b	4.43±0.5010a	3.061
Expansion ratio		4.45±0.049b	4.59±0.021a	3.61±0.021c	759.434
Nutritive Value	Moisture %	3.06 ± 0.065a	3.08± 0.008a	3.22 ± 0.014a	1.99
	Fat g/100g	6.32 ± 0.037a	6.54 ± 0.037b	6.86 ± 0.045ba	5.29
	Protein g/100g	15.54± 0.093a	15.46 ± 0.022a	15.50 ± 0.022a	0.069
	Carbohydrate g/100g	71.89 ± 0.014a	71.74 ± 0.014a	71.63± 0.008a	0.234
	Dietary fibre g/100g	11.59 ± 0.014a	11.62 ± 0.022a	12.16 ± 0.008b	5.23
	Sodium mg/100g	1349.01 ± 0.073b	1346.15 ± 0.014b	135.3±0.037a	1.139E4

swiftly. It was noted that 100g to 200g samples gave the best results with no burning during puffing process in the karahis and could be processed with constant stirring. Also, the percentage of puffed grains was highest in this case with an efficiency of 93-94%.

As reported in Table 2, It was found that the puffing of hydrated/moisture added grains was not feasible for the manual puffing process because of low puffing efficiency observed. However, several studies have shown conditioning as an efficient pre-treatment for puffing, there is a scope for this study to be taken further with proper control.[23,27,30]

In the case of salt puffing, salt needed to be changed periodically and thus, it was not found to be very cost-efficient operation. Also, it led to a salty product with high sodium and that may have also resulted in a low OAA score of 3.25 ± 0.50. The sample when subjected to analysis found sodium to be 1338.42 ± 0.012 mg/100g, similar to market procured samples suggesting that those were puffed in salt. Grittiness was observed in the case of sand puffing process, giving a low OAA score of 2.5 ± 0.58 and therefore not recommended. Considering the results from Table 2, clean grains without any pre-treatment were subjected to the manual puffing process. As per Table 3, it was observed that the grains with moisture contents in the range of 11-12.5% gave acceptable puffing efficiency of more than 85%. The samples having more moisture of around 14% required a separate drying time for 2-3 days in the puffing room before they were subjected to puffing. However, this study could not be concluded for any seasonal variations in the moisture content as storage in the village was under various conditions.

Manually puffed grains got lower score for appearance (3.85±0.0.3601) than the machine puffed market samples (A and B, 4.43±0.499 and 4.23±0.499, respectively) (Table 4). The lesser whiteness of the manually puffed grains could be attributed to lower expansion ratio during the manual process. It was also observed that the machine puffed grains were lighter in colour than the traditionally puffed grains due to better expansion volume in machine puffing. Manually puffed samples with a score of 4.13±0.4682 were crunchier than machine puffed samples may be due to a minor fraction of unpuffed, roasted grains in the final product. No significant difference was found in the overall acceptability of machine puffed and manual traditionally puffed amaranth grains. Therefore, the traditionally puffed amaranth grains proved to be acceptable for consumption and inclusion in various ready to eat recipes.

Estimation of the nutritive values reported that puffed amaranth grains provided a good amount of protein (15.50 ± 0.02g per 100g) and dietary fibre (12.16± 0.008g per 100g) (Table 4). This has also been reported in a study by Ogrodowska D. et al in 2014 where it was reported that puffing as a process has no deteriorating effect on the protein value of amaranth grain.[25] There was no significant difference in the sample means for moisture, fat, dietary fibre values ($F_{2,15}$= value greater than 1, p>0.05). For carbohydrate and protein values, again the difference was non-significant as F value is less than 1 at p>0.05 (Table 4). However, the sodium level of manual puffing process was significantly different than the machine puffed market samples ($F_{2,15}$=1.139E4, p<0.001). Post hoc testing revealed that the means for market samples formed a different homogeneous subset than the manually puffed samples. No significant difference was found between market samples A and B but these varied significantly from manually puffed samples computed at alpha 0.05 level.

The scaling up of the production process was operationalized as per the designed process. Skill efficiencies were noted with a help of a learning curve that provided to understand individual capacities of women processing the grain into puffed grain. The capacities ranged from 2250 kg – 3250 kg per month/ woman. A production of 34,936 kg of puffed amaranth grain during FY 2020-21 was low because of pandemic but also depicted potential of a sustainable business.

5. Conclusion

Manually puffed amaranth had comparable nutritive value and lower sodium content when compared with machine puffed samples. Since, the machine puffed samples were lighter in colour and had better expansion volume, a further study can be undertaken to understand the conditioning of grain with hydration to achieve moisture equilibrium that may result in better expansion volume of the manually puffed grain. Nevertheless, this model has a potential to not only provide livelihood opportunities but also promote better community health with a nutritious, indigenous grain offering.

6. Source of Funding

No funding sources.

7. Conflict of Interest

No conflict of interest.

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