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Research Article

Design and Development of Infrared Batch Heating Chamber for Reduction of Moisture Content to Enhance the Storability of Ragi (*Eleusine coracana*) Flour

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ABSTRACT

Finger millet has a three-month shelf life, and also need proper preservation and packaging processes are essential. Infrared radiation treatments with wavelengths ranging from 0.5 to 100 meters are used to eliminate moisture and improve the shelf life of food products. A infrared batch dryer has been designed to decreases the moisture content of sample as it is exposed to high temperatures, but increases as storage time increases. A sample treated at 110°C for 2, 3, 4 minutes shows minimum moisture content after 90 days storage, which is good for flour. The IR treatment at 110°C for 2 minutes is best for use, followed by S15 and S13, treated at 110°C for 3 and 1. The sample treated at 110°C for 2,3,4 minutes showed minimum moisture content after 90 days storage, which is good for flour. The IR treatment at 110°C for 4 minutes *i.e.* S16 is best for use followed by S15 and S13, treated at 110°C for 3 and 4. The sample treated with 50°C for 1 minute and fresh (control) flour sample showed nearly similar effect on physico-chemical and nutritional properties of ragi flour as compared to sample treated at 70°C, 90°C and 110°C. The IR treatment at 90°C for 2 minutes *i.e.* S10 is best for use followed by S16 and S14, treated at 110°C for 4 and 2. Finally, the IR treatment at 110°C for 2 minutes *i.e.* S14 is best for use.

Keywords: Finger millet; Infrared radiation; Infrared batch dryer; Pulses; Ragi

INTRODUCTION

The right to food is essential for holistic well-being, and India is committed to becoming a malnutrition-free country. However, the nutrient consumption situation in India is still severe, with cereals, vegetable pulses, and non-vegetarian goods decreased in every second family. The term 'millet' includes a number of coarse or inferior grains that have high nutritive value like bajra, jowar and ragi. Millets are also known as 'dry crops' because they are grown in the drier parts of the country. Ragi crop in India has covered 10.14 lakh ha (25.06 lakh acres) during kharif 2021 to 2022. Small millets are nutritionally superior to rice and wheat, providing low-cost proteins, minerals and vitamins to the poor [1]. They have indefinite storage life and untapped grain yield potential, making them potential future food crops in rain fed areas.

Tropical finger millet scientifically known as *Eleusine coracana* is cultivated from sea level to 3,000 masl. Due to its great nutritional value and advantageous health effects, it is a staple diet in Africa and India. Finger millet is one of the rich sources of nutrients. It is composed of dietary fiber (18%), calcium (344 mg/100 g), tannins (0.04% to 3.47%), phytate (0.48%), oxalate (0.27%), cyanide (0.17%), saponins (0.36%), phenolics (0.3% to 3%) and polyphenols. They are also rich in amino acids (isoleucine, phenylalanine, leucine and methionine), minerals (calcium, phosphorus and iron) and vitamins, including B (1.71 mg) and E (22 mg). Finger millet is a popular food in southern India due to its high nutritional content [2]. It is consumed in the form of a porridge called Ragimudde, which is the staple diet of many residents of South Karnataka. Though the finger millet and its product like flour is highly enriched with nutrition the preservation and packaging techniques are more important for us. From various study it has been seen that the storage/shelf life of finger millet is generally observed 3 months for maximum. So there is a need to extend shelf life by making dry product by

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efficient and low cost dryer which can be used by farmer on field for low cost postharvest management and packaging as well.

Infrared radiation treatments are being used to reduce moisture and extend shelf life of food products, with wavelengths ranging from 0.5 to 100 meters. In both liquid and solid meals, IR heating can be used to kill bacteria, spores, yeast, and mould. As a result, the study is to design and develop an infrared batch dryer suitable for extension of shelf life of ragi flour and also to identify the optimum irradiation dose and disinfestations of grains to improve the shelf life and to study the physical, microbiological and sensory quality of radiation processed ragi before, during and after storage and cut down on waste and enhance storage conditions [3].

MATERIALS AND METHODS

Design and development of IR batch heating chamber was done as per requirement and fabricated using food grade stainless material.

Ragi grains were shortened washed, and sun dried until they reached 13% moisture. They were ground separately using a laboratory scale grinding mill, sieved with mechanical mesh, and weighed with an analytical balance to make a 100 gram sample. The ragi flour was subjected to IR heat treatment. For the treatment the ragi flour was spread over the tray with 2 cm depth and kept inside the chamber for heat treatment which has been carried out at different temperature *i.e.* 50°C, 70°C, 90°C, and 110°C and four time interval *i.e.* 1,2,3 and 4 minutes [4,5]. After treatment the 100 g sample was packed in polyethylene pouch and heat sealed. Samples were prepared by grinding and treating the samples by IR Heat treatment at different time and temperature. Samples were stored in polyethylene bag for a period of three months. Physicochemical and nutritional properties of ragi flour were determined periodically in laboratory (Table 1) [6].

Table 1: Samples were prepared by grinding and treating the samples by IR heat treatment at different time and temperature.

Sample	IR treatment		Sample	IR treatment	
Nomenclature	Temperature in °C	Time in minutes	Nomenclature	Temperature in °C	Time in minutes
$T_{50}T_1$	50	1	$T_{90}T_1$	90	1
$T_{50}T_2$	50	2	$T_{90}T_2$	90	2
$T_{50}T_3$	50	3	$T_{90}T_3$	90	3
$T_{50}T_4$	70	4	$T_{90}T_4$	90	4
$T_{70}T_1$	70	1	$T_{110}T_1$	110	1
$T_{70}T_2$	70	2	$T_{110}T_2$	110	2
$T_{70}T_3$	70	3	$T_{110}T_3$	110	3
$T_{70}T_4$	70	4	$T_{110}T_4$	110	4
FF	Sample without IR treatment				

RESULTS AND DISCUSSION

A rectangular chamber of stainless steel (SS 304) of 18 gauge (1.27 mm), a food grade metal containing racks. The drying chamber has a length of 38.5 cm, width of 15 cm and height of 75 cm as outer dimension and having length, width and height, 30, 10 and 60 cm respectively as inner dimensions. This chamber hoses the trays which are used to hold the sample for heat treatment in the chamber. In the chamber, the slots are spaced 5 cm apart according to the food material size, shape, and density for required treatment. The slots are used for heat treatment and drying of the product [7,8]. The tray's dimensions (length, width and height) are 28.5 cm, 9.00 cm, and 2.5 cm respectively. Each side of the double walled drying chamber is insulated with glass wool to reduce heat loss considering the drying temperature, availability and cost of insulating material.

The double walled door is attached with hinges and heat resistance rubberized sealing system. The drying chamber is the part of the dryer where the food materials to be dried are fed and drying takes place. The developed infrared heat dryer can be operated with single phase at 220 v and maintain a maximum temperature of 350°C within 10 minutes. The temperature can be maintained to a desired temperature by setting the temperature in the controller, but the actual product temperature remains below 10°C due to short time of treatment. Moisture removed from the product is escaped from the chamber through the exhaust fan [9-12].

All the samples (100 g each) were treated and packed in polyethylene bag. The observed data of moisture content clearly indicate that the moisture content is inversely affected by the temperature. It means when the sample exposed to high temperature and for more time the moisture content decreases [13].

During the expansion in time of storage moisture content increases and affect the flour quality directly [14]. As per the treatment given the sample treated at 110°C for 2, 3, 4 minutes shows minimum moisture content after 90 days of storage which indicate good flour quality. The graph and table below shows IR treatment at 110°C for 2 minutes is best for use followed by $T_{100}T_3$ and $T_{110}T_1$, treated at 110°C for 3 and 1 minute (Figure 1) [15,16].

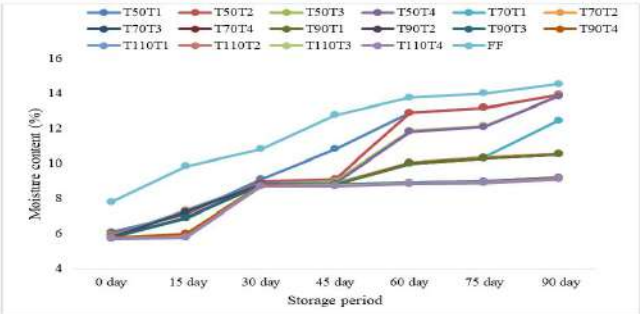

Figure 1: The graph shows effect of storage period on moisture content of IR treated ragi flour.

The effect of operating variables on the drying period using analysis of variance (ANOVA; Microsoft Excel) was carried out. According to the ANOVA results shown in table the moisture content was strongly influenced by temperature [17]. The analysis of variance for the effect of storage period on moisture content of IR treated ragi flour is given in Table 2 and 3. As per the above given table the F value calculated at α=0.05, the factor A in IR treated ragi flour shows significant variations in moisture content while no variation found in factor B [18].

Table 2: Effect of storage period on moisture content of IR treated ragi flour.

Treatment	0 day	15 days	30 days	45 days	60 days	75 days	90 days
$T_{50}T_1$	6.1	7.1	9.1	10.8	12.9	13.19	13.9
$T_{50}T_2$	5.98	7.13	8.98	9.1	12.9	13.19	13.93
$T_{50}T_3$	5.89	7.23	8.89	8.98	11.86	12.15	13.85
$T_{50}T_4$	5.87	7.31	8.87	8.89	11.81	12.1	13.83
$T_{70}T_1$	5.85	7.3	8.85	8.87	10.07	10.36	12.46
$T_{70}T_2$	5.81	7.29	8.81	8.85	10.05	10.34	10.56
$T_{70}T_3$	5.8	7.25	8.8	8.81	10.01	10.3	10.52
$T_{70}T_4$	5.8	6.9	8.8	8.8	10	10.29	10.51
$T_{90}T_1$	5.79	6.89	8.79	8.8	10	10.29	10.51
$T_{90}T_2$	5.79	6.87	8.79	8.79	8.91	8.97	9.19
$T_{90}T_3$	5.76	6.87	8.76	8.79	8.91	8.97	9.19
$T_{90}T_4$	5.75	6	8.75	8.76	8.88	8.94	9.16
$T_{110}T_1$	5.71	5.81	8.71	8.75	8.87	8.93	9.15
$T_{110}T_2$	5.73	5.8	8.73	8.73	8.85	8.91	9.13
$T_{110}T_3$	5.7	5.75	8.7	8.71	8.83	8.89	9.11
$T_{110}T_4$	5.7	5.76	8.7	8.7	8.82	8.88	9.1
FF	7.8	9.85	10.8	12.76	13.76	14.01	14.56

Table 3: ANNOVA for the effect of storage period on moisture content of IR treated ragi flour.

Source of variation	DF	Sum of squares	Mean squares	F-calculated	Significance	C.D.	SE (d)	SE (m)
Factor A	3	71.762	23.921	5.623*	0.00136	1.096	0.551	0.39
Factor B	3	3.131	1.044	0.245*	0.86451	N/A	0.551	0.39
A × B	9	1.313	0.146	0.034*	1	N/A	1.103	0.78
Error	96	408.419	4.254					
Total	111	484.624						

Note: *F calculated at α=0.05, Factor A=Temperature, Factor B=Time

According to the findings, the original moisture content was 10.60% on average before radiation [19]. After one month of storage, the moisture content of irradiation foxtail millets ranged from 10.48 to 10.34 percent (d.b), while the control grain had the maximum moisture content (10.50 per cent). This can be attributed to the higher bed temperature of particles in the bed, which increased the intraparticle moisture diffusion to the surface of the solid, resulting in a higher drying rate and the drying was strongly influenced by air temperature (81.26% of the influence), followed by solids loading (16.98%). Air velocity had a very small influence on the drying period (3.2%) [20].

CONCLUSION

IR heating is a unique process; however, presently, the application and understanding of IR heating in food processing is still in its infancy. It is further evident that IR heating offers many advantages over convection heating, including greater energy efficiency, heat transfer rate, and heat flux that results in time-saving as well as increased production line speed.

As per the experiments conducted for the investigation of effect on physico-chemical and nutrient properties of ragi flour during storage after IR heat treatment in designed and developed Infrared batch heating chamber, finally it can be concluded that as per the treatment given to all the samples the sample treated at 110°C for 2 minutes shows minimum changes over the period of 90 days storage which is good for flour and the IR treatment at 110°C for 2 minutes *i.e.* $T_{110}T_2$ is best for use.

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