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Effect of various storage condition on quality of dried cluster bean (*Cyamopsis tetragonoloba*)

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ABSTRACT

Cluster bean (*Cyamopsis tetragonoloba* L.) or guar bean, an annual legume grown in India, USA, Australia, Pakistan and Africa, is a rich source of soluble fibre content. For improving its colour in final products, the samples were blanched at 80°C, for 10 min in a hot water with sodium bicarbonate, sodium benzoate and magnesium oxide (each at 1.5% concentration). The cluster beans were blanched and dried in different drying methods viz. sun drying, tray drying (thin layer and deep bed at 40° and 50°C) and rotary drying (40° and 50°C after filling 40 and 60% dryer volume). After drying samples were packaged under vacuum as well as normal condition in low density poly ethylene (LDPE) and poly propylene (PP) bags and stored at ambient condition. Storage studies conducted for three months revealed that dried cluster bean samples stored with LDPE had good quality than the samples stored with PP. Vacuum packed samples were found with good quality than the normally packed samples. In overall the optimized combination of drying and packaging was rotary dryer filled to 40% dryer volume, dried at 40˚C packaged in LDPE under vacuum condition stored at ambient. Cluster bean samples of this treatment recorded 9.42% (db) moisture content, 0.94% protein, 0.478 water activity, - 0.721 as change in greenness value, 6×10^3 cfu/gdm of fungal population and 4×10^5 cfu/gdm of bacterial population after 90 days of storage.

Key words: LDPE, Polypropylene packaging, Protein content cluster bean, Sun drying, Vacuum packaging

Cluster beans (*Cyamopsis tetragonoloba* L.) or guar beans, an annual legume, bears white or rose flowers, flatter, and is smaller cousin of the regular green beans. It is widely grown in India, Pakistan, Texas in USA, Australia and Africa. About 80% of the world production of cluster bean comes from India. Edible portion (100 g) of cluster bean contains, moisture 81.0 g, carbohydrate 10.8 g, protein 3.2 g, soluble dietary fibre 3.09 g, fat 0.4 g and minerals 1.4 g. Cluster bean have several health benefits in both vegetable and powder form. Beans are very nutritious and used after heat treatment like blanching to destroy the trypsin inhibitor and other anti-nutritional factors. Cluster bean is rich in soluble dietary fiber and lowers blood cholesterol levels. Guar gum is a common ingredient in fiber-rich drinks marketed as health drinks. Though cluster bean contains good nutritional value, they fetch less price in the market due to poor post-harvest handling. Scientific and technical knowledge are also scanty related to processing of cluster bean as legume vegetable. Hence a study was conducted to extend its shelf life by drying with proper pretreatments and packaging.

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MATERIALS AND METHODS

Sample preparation

Fresh cluster beans, variety CP 78 was purchased directly from farmers' field from villages of Coimbatore district, Tamil Nadu. Fully matured and fresh cluster beans were washed and excess surface moisture was removed using tissue papers. Beans were blanched in hot water containing food additives like magnesium

oxide, sodium bicarbonate, sodium benzoate (each 1.5%) at 80°C for 10 min to inhibit the activities of enzyme trypsin inhibitor and to retain green colour. The pretreated samples were dried using different drying methods viz. sun drying, tray drying (thin layer and deep bed at 40° and 50°C) and rotary drying (40° and 50°C after filling 40 and 60% dryer volume).

After drying, cluster beans were packaged in vacuum packaging (VP) and normal air packaging (NAP) with low density polyethylene (LDPE) pouches (100 microns) and polypropylene (PP) pouches (60 microns). The dried samples were vacuum packed at vacuum to 750 mm of Hg using lab model vacuum packaging machine (M/s. Savanna, India. Model-Qs 400VSG). The packed beans were stored at room condition (temperature 28±2°C and relative humidity 60±5 per cent) and in every 30 days samples were taken for quality analysis.

Quality analysis

Moisture content of cluster beans were determined using a hot air oven (AOAC 2005) for uncrushed materials. The water activity a_w was measured using water activity meter (Aqua Lab, USA).

The colour of cluster beans were measured using colour meter (CFLX-45, Hunterlab, USA). Colour was measured from five different samples from each experiment and the mean value was used. Since, greenness of the bean is the commercially important colour parameters, a^* coordinate was measured and the difference in greenness was calculated using eq.1 as proposed by Devahastin et al. (2004).

$$\text{Da} = \frac{a - a_i}{a_i} \qquad (1)$$

where, a and a_i are the green colour value of final and initial sample.

The microbial population was assessed by standard plate count method for the enumeration of total bacteria, fungi and coli forms in the sample.

The protein content was estimated following Micro-Kjeldahl method as represented by Sadasivam and Manikam (1992), using a laboratory kjel plus equipment (REC 22238-A2, Pelican equipments, India). Dried cluster beans sample of 0.3 g was ground and transferred into the digestion tube. To this, 10 ml of concentrated sulphuric acid and 3 g of digestion activator (mixture of potassium sulphate or sodium sulphate with copper sulphate in 5:1 ratio) were added. The content was left undisturbed overnight to enhance digestion and then the material was digested in the digestion flasks at a temperature of 420˚C. The sample was distilled by passing steam; ammonia liberated due to addition of alkali was trapped in 4% boric acid. The ammonia in boric acid was titrated against the standardized HCl using mixed indicator (0.1 g bromocresol and 0.1 g methyl red in 400 ml of 95% ethanol). The titre value was noted down at the end point when the colour turns from green to light pink. The per cent nitrogen was calculated using titre value. The protein content was obtained by multiplying the per cent of nitrogen with the factor 6.25:

$$\textit{Nitrogen}, \text{N}\ (\%) = \frac{(V_1 - V_2) \times N_a \times 14.01}{W \times 1000} \times 100 \qquad (2)$$

where, V_1, titre value, volume of HCl consumed by the sample in ml; V_2, volume of the blank in ml; W,weight of sample in g. N_a, normality of acid. The protein content was calculated by N × 6.25 and expressed in percentage.

Statistical analysis

The data collected on various quality parameters during the study were statistically analyzed using software Minitab 4.0 version for four factorial complete randomized design.The level of significance of drying methods (D), packaging methods (M) and storage periods (S) on different quality parameters were analyzed using two way ANOVA.

RESULTS AND DISCUSSION

From the statistical analysis, it was found that effects of drying methods (D), packaging methods (M) and storage periods (S) on all measured quality parameters of bean was highly significant ($P<0.01$) at single factor as well as interaction level.

Effects of different packaging material and condition on moisture content

The change in the moisture content in the dried, packaged and stored samples was determined and presented in Table 1. These results are in accordance with Jayashree (2013) who reported an average moisture content of fresh and dried ginger rhizomes as 81.70 and 8.85% (wb). Results revealed (Table 2) that irrespective of drying methods adopted, bed thicknesses followed, drying air temperatures used, packaging materials and packaging methods followed, increase in storage period recorded an increase in moisture content. It may be due to the permeability of packaging material, hygroscopic nature of the dried cluster beans samples and partial water vapour difference that existed between cluster beans and outside atmosphere. Both the packaging materials used for packaging the dried cluster beans samples recorded almost equal moisture content in both types

Table 1 Effects of different packaging materials and packaging methods on moisture content of dried cluster bean samples stored during storage

Drying method	Storage period, days	Thin layer / 40% dryer volume*				Deep bed / 60% dryer volume *			
		LDPE		PP		LDPE		PP	
		NAP	VP	NAP	VP	NAP	VP	NAP	VP
Sun	0	11.67	11.67	11.67	11.67	12.02	12.02	12.02	12.02
CCF	30	12.22	12.12	12.24	12.14	12.54	12.34	12.56	12.42
	60	12.42	12.28	12.44	12.3	12.68	12.58	12.7	12.60
	90	12.57	12.34	12.58	12.36	12.76	12.70	12.78	12.72
Tray dryer 40˚C	0	8.42	8.72	8.42	8.42	9.50	9.50	9.50	9.50
	30	9.36	9.24	9.56	9.30	9.88	9.76	9.9	9.78
	60	9.72	9.38	9.8	9.60	9.99	9.89	10.01	9.91
	90	9.9	9.48	9.93	9.72	10.1	9.95	10.12	9.97
Tray dryer 50˚C	0	8.30	8.30	8.33	8.30	8.77	8.77	8.77	8.77
	30	9.18	9.26	9.30	9.28	9.62	9.32	9.64	9.34
	60	9.64	9.39	9.68	9.4	9.85	9.48	9.88	9.5
	90	9.78	9.49	9.94	9.51	9.98	9.6	9.99	9.63
Rotary dryer 40˚C	0	8.91	8.91	8.91	8.91	9.37	9.37	9.37	9.37
	30	9.34	9.30	9.39	9.26	9.78	9.67	9.81	9.69
	60	9.47	9.35	9.56	9.35	9.96	9.75	9.98	9.76
	90	9.57	9.42	9.65	9.42	10.01	9.8	10.05	9.86
Rotary dryer 50˚C	0	8.54	8.54	8.54	8.54	9.03	9.03	9.03	9.03
	30	9.15	8.92	9.57	9.22	9.61	9.34	9.63	9.36
	60	9.36	9.18	9.71	9.40	9.76	9.43	9.78	9.45
	90	9.54	9.30	9.76	9.52	9.83	9.48	9.85	9.5

*Applicable only to rotary dryer

of packaging methods followed. This may be due to low gas barrier properties of LDPE and PP packaging materials. From table, it is also seen that thin layer, higher temperature (50°C) and 40% dryer volume filled samples recorded lesser moisture content at any point of time during storage as compared to deep bed, low temperature (40°C) and 60% dryer volume filled samples.

Effects of different packaging materials and condition on protein content

The change in the protein content in the dried, packaged and stored samples is presented in Table 2. Irrespective of drying methods adopted, bed thicknesses followed, drying air temperatures used, packaging materials and methods followed, increase in storage period recorded a decrease in protein content (Table 2). In case of tray and rotary dryers dried samples at 40° and 50°C either as thin layer (or) deep bed, filled to 40 and 60% dryer volume recorded a protein content value of 0.96±2% on day one of storage and it got decreased to 0.885±0.025% after 90 days of storage. However, among different experiments conducted, pretreated cluster beans samples dried in a rotary dryer at 40°C filled to 40% dryer volume packaged in LDPE under vacuum condition was best. Niranjanaa Devi (2011) reported that the protein values of retort processed and stored spent layer chicken meat were 23.74 and 20.58 % on the day one of storage and after 105 days of storage, respectively.

Effects of different packaging materials and condition on water activity (a_w)

The change in the water activity in the dried, packaged and stored samples is presented in Table 3. Irrespective of drying methods adopted, bed thicknesses followed, drying air temperatures used, packaging materials and packaging methods followed, increase in storage period recorded an increase in water activity value. It may be due to increase the moisture content of stored samples during storage. It is further seen that all the samples dried in a tray dryer and rotary dryer recorded a water activity value less than 0.500, even after three month storage (Table 3). This clearly indicated that dried, packaged and stored samples are highly safe as per as spoilage by microorganism is considered. Among all experiments conducted, pretreated cluster beans samples dried at 50˚C in a rotary dryer filled to 40% dryer volume, packaged in LDPE packaging material under vacuum

Table 2 Effects of different packaging materials and packaging methods on protein content (%) of dried cluster bean samples stored during storage

Drying method	Storage period, days	Thin layer / 40% dryer volume				Deep bed / 60% dryer volume*			
		LDPE		PP		LDPE		PP	
		NAP	VP	NAP	VP	NAP	VP	NAP	VP
Sun	0	0.67	0.67	0.67	0.67	0.68	0.68	0.68	0.68
CCF	30	0.65	0.65	0.64	0.64	0.66	0.67	0.65	0.67
	60	0.63	0.64	0.62	0.63	0.64	0.66	0.63	0.66
	90	0.61	0.62	0.60	0.61	0.62	0.65	0.61	0.64
Tray dryer 40˚C	0	0.96	0.96	0.96	0.96	0.98	0.98	0.98	0.98
	30	0.93	0.94	0.92	0.94	0.94	0.96	0.94	0.95
	60	0.91	0.92	0.90	0.91	0.92	0.94	0.91	0.93
	90	0.89	0.90	0.88	0.89	0.90	0.92	0.89	0.91
Tray dryer 50˚C	0	0.94	0.94	0.94	0.94	0.97	0.97	0.97	0.97
	30	0.90	0.92	0.89	0.91	0.93	0.95	0.92	0.94
	60	0.88	0.90	0.87	0.89	0.91	0.93	0.90	0.92
	90	0.86	0.88	0.85	0.87	0.89	0.91	0.88	0.90
Rotary dryer 40˚C	0	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98
	30	0.94	0.96	0.93	0.96	0.94	0.96	0.93	0.95
	60	0.92	0.95	0.91	0.95	0.92	0.94	0.91	0.93
	90	0.90	0.94	0.89	0.93	0.91	0.93	0.90	0.92
Rotary dryer 50˚C	0	0.95	0.95	0.95	0.95	0.96	0.96	0.96	0.96
	30	0.91	0.93	0.90	0.92	0.92	0.94	0.91	0.93
	60	0.89	0.91	0.88	0.90	0.90	0.92	0.89	0.91
	90	0.87	0.89	0.86	0.88	0.88	0.90	0.87	0.89

*Applicable only to rotary dryer

Table 3 Effects of different packaging materials and packaging methods on water activity (a_w) of dried cluster bean samples stored during storage

Drying method	Storage period, days	Thin layer / 40% dryer volume				Deep bed / 60% dryer volume*			
		LDPE		PP		LDPE		PP	
		NAP	VP	NAP	VP	NAP	VP	NAP	VP
Sun	0	0.472	0.472	0.472	0.472	0.485	0.485	0.485	0.485
CCF	30	0.532	0.493	0.530	0.494	0.532	0.502	0.535	0.504
	60	0.559	0.497	0.56	0.498	0.571	0.526	0.573	0.528
	90	0.571	0.502	0.573	0.503	0.601	0.539	0.604	0.541
Tray dryer 40˚C	0	0.44	0.44	0.44	0.44	0.479	0.479	0.479	0.479
	30	0.471	0.457	0.474	0.459	0.49	0.484	0.49	0.485
	60	0.482	0.467	0.486	0.469	0.496	0.491	0.497	0.492
	90	0.489	0.476	0.49	0.478	0.499	0.495	0.500	0.496
Tray dryer 50˚C	0	0.426	0.426	0.426	0.426	0.452	0.452	0.452	0.452
	30	0.458	0.450	0.460	0.452	0.474	0.459	0.476	0.46
	60	0.472	0.466	0.475	0.468	0.487	0.473	0.489	0.474
	90	0.481	0.472	0.486	0.475	0.494	0.479	0.496	0.48
Rotary dryer 40˚C	0	0.454	0.454	0.454	0.454	0.465	0.465	0.465	0.465
	30	0.462	0.456	0.46	0.458	0.48	0.478	0.481	0.478
	60	0.478	0.470	0.478	0.462	0.489	0.481	0.490	0.481
	90	0.482	0.478	0.482	0.476	0.491	0.482	0.492	0.483
Rotary dryer 50˚C	0	0.440	0.44	0.44	0.44	0.455	0.455	0.455	0.455
	30	0.456	0.452	0.460	0.456	0.475	0.459	0.475	0.459
	60	0.468	0.460	0.472	0.462	0.484	0.472	0.484	0.472
	90	0.476	0.466	0.480	0.470	0.489	0.478	0.489	0.478

*Applicable only to rotary dryer

condition was best. Similar water activity results were reported by Kulandhisamy et al. (2010) in tomato slices, Kaleemullah and Kailappan (2006) in chillies, Sudagar (2012) in moringa pods during drying and storage.

Effects of different packaging materials and condition on change in colour value (Δa)

The change in colour value (Δa) in the dried, packaged and stored samples is presented in Table 4. Irrespective of drying methods adopted, bed thicknesses followed, drying air temperatures used, packaging materials and packaging methods followed, increase in storage periods recorded an increase in change in colour value (Δa) i.e. green colour decreased with increase in storage period. This may be due to drying operation, which changed the surface characteristics of cluster beans samples and hence altered the reflectivity and colour.

Chemical changes in chlorophyll pigments were caused by heat and oxidation during drying. In general, longer drying times and higher drying temperatures produce greater pigment losses. Oxidation and residual enzyme activity also caused browning of products during storage. Another important observation made in the present study is that deep bed dried samples and 60% dryer volume filled samples recorded increased change in colour value (Δa) as compared to thin layer and 40% dryer volume filled and dried samples. This may be due to the effect of drying at higher temperature and prolonged heating at the same temperature due to increased bed thickness and or increased filled volume.

Among all the experiments conducted, pretreated cluster beans samples filled to 40% dryer volume in a rotary dryer dried at 40°C, packaged in LDPE under vacuum condition recorded minimum change in colour value (Δa) during drying and during storage period of three months. Sakhale et al. (2007) reported that hot water blanching with magnesium oxide 0.1% followed by drying retained greenness of curry leaves higher compare to other conditions. Hii et al. (2008) reported that colour analyses of dried cocoa beans showed no significant difference ($P > 0.05$) in terms of L*, a*, b* and h* values between the sun dried and oven dried samples. Sudha (2009) reported colour (b* value) of fresh jackfruit bulbs as 54.45 and among all the treatments studied, jackfruit bulbs in jack fruit pulp of 20°B, packaged in cans, processed at 85˚C and stored for 12 months recorded maximum 'b*' value of 54.14, which was almost equal to that of fresh bulbs.

Table 4 Effects of different packaging materials and packaging methods on change in green colour value ('Δa') of dried cluster bean samples stored during storage

Drying method	Storage period, days	Thin layer / 40% dryer volume				Deep bed / 60% dryer volume*			
		LDPE		PP		LDPE		PP	
		NAP	VP	NAP	VP	NAP	VP	NAP	VP
Sun	0	-0.763	-0.763	-0.763	-0.763	-1.018	-1.018	-1.018	-1.018
CCF	30	-0.803	-0.793	-0.806	-0.795	-1.043	-1.030	-1.046	-1.032
	60	-0.820	-0.803	-0.823	-0.806	-1.065	-1.046	-1.067	-1.048
	90	-0.836	-0.813	-0.839	-0.815	-1.077	-1.056	-1.079	-1.058
Tray dryer 40˚C	0	-0.805	-0.805	-0.805	-0.805	-1.112	-1.112	-1.112	-1.112
	30	-0.837	-0.825	-0.841	-0.828	-1.151	-1.147	-1.154	-1.149
	60	-0.856	-0.835	-0.861	-0.837	-1.170	-1.165	-1.171	-1.166
	90	-0.871	-0.843	-0.876	-0.848	-1.180	-1.170	-1.183	-1.173
Tray dryer 50˚C	0	-2.560	-2.560	-2.560	-2.560	-2.720	-2.720	-2.720	-2.720
	30	-2.598	-2.582	-2.602	-2.588	-2.792	-2.778	-2.806	-2.800
	60	-2.646	-2.612	-2.656	-2.632	-2.816	-2.802	-2.826	-2.818
	90	-2.692	-2.648	-2.700	-2.656	-2.876	-2.854	-2.892	-2.864
Rotary dryer 40˚C	0	-0.699	-0.699	-0.699	-0.699	-0.761	-0.761	-0.761	-0.761
	30	-0.730	-0.711	-0.732	-0.714	-0.788	-0.779	-0.790	-0.781
	60	-0.741	-0.716	-0.745	-0.719	-0.799	-0.788	-0.801	-0.790
	90	-0.752	-0.721	-0.755	-0.726	-0.805	-0.794	-0.809	-0.796
Rotary dryer 50˚C	0	-0.737	-0.737	-0.737	-0.737	-0.771	-0.771	-0.771	-0.771
	30	-0.768	-0.752	-0.771	-0.755	-0.795	-0.787	-0.798	-0.789
	60	-0.778	-0.762	-0.780	-0.765	-0.803	-0.796	-0.805	-0.798
	90	-0.783	-0.768	-0.785	-0.770	-0.806	-0.800	-0.809	-0.802

*Applicable only to rotary dryer

Effects of different packaging materials and condition on fungal and bacterial population

During storage, fungal population increased from zero value on day one of storage to less than 9 × 10^3cfu/gdm at the end of 3 months storage. Vacuum packaged samples recorded lesser microbial load as compared to the corresponding sample packaged as normal air packaging. This may be due to non-availability of required quantity oxygen in the vacuum packaged samples for the microbes to grow. Pretreated cluster beans samples dried in a rotary dryer filled to 40% dryer volume dried at 50°C, packaged in LDPE film under vacuum condition recorded minimum fungal population of 0, 1, 3 and 6× 10^3cfu/gdm on day one of storage, 1st, 2nd and 3rd months of storage, respectively.

Among all drying and packaging studies conducted, pretreated cluster beans samples, dried in a rotary dryer at 50°C filled to 40% dryer volume, packaged in LDPE film under vacuum packaging condition recorded a minimum bacterial population of 0, 0, 1 and 2× 10^5cfu/gdm after 1, 30 , 60, and 90 day of storage, respectively. On the other hand, pretreated cluster beans dried on cement concrete floor directly under sunlight, packaged in PP as normal air packaging (NAP) recorded maximum bacterial population of 0, 1, 4, and 8× 10^5cfu/gdm after day one, 30th, 60th and 90th day of storage, respectively. All other samples recorded a bacterial population in between these two values. Similar microbial population results were reported by Kavitha (1999) for greenhouse dried copra samples which was 2.83 × 10^6 cfu and 3.99 × 10^6 cfu for sun dried samples; and Sudha (2009) for jack fruit bulbs found that it varied from 5.11 to 5.46 log cfu/g.

CONCLUSION

In order to extend the shelf life of cluster bean, a study was carried out. The effect of different drying method followed by different storage condition on various quality parameters of cluster bean were evaluated. Among all the drying, packaging and storing studies conducted, pretreated cluster bean sample dried in a rotary dryer at 50°C filled to 40% dryer volume, packaged in LDPE film under vacuum packaging condition recorded minimum bacterial population of 0 and 2× 10^5cfu/gdm after 1 and 90th day of storage, respectively. These findings would be useful for the stakeholder to adopt the optimized condition while processing cluster bean.

REFERENCES

AOAC (2005) AOAC official methods of analysis, 18th edn. Natural Toxins, AOAC International, Gaithersburg, MD, USA.

Davahastin S, Suvarnakuta P, Sononroonnarit S, Mujumdar AS (2004) A comparative study of low pressure superheated steam and vacuum drying of a heat sensitive material. Drying Technology **22**(8): 1845–1867.

Hii CL, Lawb CL, Clokea M, Suzanna S (2008) Thin layer drying kinetics of cocoa and dried product quality. Biosystems engineering **102**: 153–161.

Jayashree E, and Visvanathan R (2013) Studies on thin layer drying characteristic of ginger (*Zingiber officinale* Rosc.) in a mechanical drier. Journal of Plantation Crops, **41**(1): 86–90.

Kaleemullah S, Kailappan R (2006) Modelling of thin-layer drying kinetics of red chillies. Journal of Food Engineering **76**: 531–537.

Kavitha CV (1999) Poly greenhouse drying of selected horticultural crops. Unpublished M.E. (Ag) Thesis. Dept. of Food and Agricultural Process Engineering, College of Agricultural Engineering, TNAU, Coimbatore (India).

Kulanthaisami S, Raj Kumar P, Venkatachalam P, Subramanian P, Ragavan GSV, Garipy Y and Orsat V (2010) Drying kinetics of tomato slices in solar cabinet dryer compared with open sun drying. Madras Agricultural Journal **97**(7-9): 287–295.

Niranjanaa Devi (2011) Studies on preparation of ready to eat spent layer chicken curry by retort processing technology. Unpublished M.Tech Thesis, Department of Agricultural Processing, Tamil Nadu Agricultural University: Coimbatore, India.

Sadasivam S, Manickam A (1992) Biochemical Methods for Agricultural Sciences. Wiley Eastern Ltd., New Delhi, India, ISBN:8122403883.

Sakhale BK, Nandene AS, Ranveer RC (2007) Studies on dehydration of curry leaves. ADIT Journal of Engineering **4**(1): 62–64.

Sudagar IP (2012) Studies on drying, packaging and storage of chewable size ready to cook moringa pods. Unpublished Ph.D. thesis. Dept. of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Sudha P (2009) Optimization of process parameters for thermal processing of Jack fruit bulbs. Unpublished Ph.D. thesis. Dept. of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.