

Mathematical modeling of cashewnut processing parameters

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Received : 08.07.2013; Revised : 20.10.2013; Accepted : 19.11.2013

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■ **ABSTRACT** : Cashew (*Anacardium Occidentale L.*) is one of the important tropical crops having high export potential due to high market value of kernels. In the study “Vegurla-4” variety of cashewnut was processed by direct steam roasting method for studying maximum per cent whole kernel recovery, drying behaviour of kernels and sensory properties of cashew kernel. The treatments were combinations of steam pressure viz., 10, 15 and 20 psi and time of steaming viz., 10, 15 and 20 min. Statistical R. B. D. analysis revealed that the treatment 20 psi with 10 min. gave maximum 90.08 per cent whole kernels. The pressure factor was significant while time factor was found to be non-significant in 3² factorial designs. The mathematical model developed gave the optimum pressure 18.76 psi for maximum shelling percentage. The treatment consisting of 15 psi and 15 min gave better result during drying study with lowest equilibrium moisture content and highest drying constant. The sensory study revealed that among treatments colour and texture varied significantly. Overall, treatment with steam pressure 20 psi and steaming time 15 min. was found to be most suitable.

■ **KEY WORDS** : Cashewnuts, Direct steaming roasting, Whole kernel recovery, Steam pressure, Steaming time, Sensory

■ **HOW TO CITE THIS PAPER** : Jain, S.K. and Chavan, P.P. (2013). Mathematical modeling of cashewnut processing parameters. *Internat. J. Agric. Engg.*, 6(2) : 497-501.

Cashew (*Anacardium Occidentale L.*) is one of the important tropical crops, which leads an international trade with prominent market share. India is largest producer, processor, exporter and second largest consumer in the world. Indian cashews are exported to more than 60 countries all over the world and over 60 per cent of cashew imported in USA are from India (Niar 1993, Prabhu, 1996). Total area in India under cultivation in year 2000-2001 was 7,20,000 ha and out of which productive area was 6,27,000 ha with annual production 4,50,000 MT giving average productivity 710 kg per ha. Export of cashew in year 2000-2001 was 81,657 MT earning Rs. 1878.5 crores and cashewnut shell oil exported was 2171 MT of value Rs. 3.73 crores.

The direct steam roasting method of cashew processing is popular in small and medium scale industries. There is large variation in steam pressure and steaming duration adopted by different industries. A study on steam roasting of raw nuts of different origin is essential and steam pressure and duration have to be optimized for maximum whole kernel recovery. Hence, the study was undertaken with objectives to study the effect of steaming pressure and time on whole kernel recovery from cashewnuts, on drying of cashew kernels and on organoleptic properties of cashew kernels. Niar (1993) reported that steaming is an alternate method to

roasting. Well dried raw nuts are steam cooked at about 120-140 psi pressure. About 6 bags can be cooked in one hour. Chattopadhyay (1996) reported that steam roasting was commonly used by most of processing units. Raw nuts were steam roasted at about 100 psi pressure for 25-30 minutes. The nuts were allowed to cool for 24 hours and then taken for shelling. Nagraja and Balsubramaniam (1998) reported that steam boiling was followed as preliminary conditioning process with steam pressure 30-150 psi and duration 30-90 minutes differed from industry to industry. In direct steaming process moisture content of kernels increases, hence, it is difficult to peel the testa. Drying is essential for easy peeling of testa and to increase its storage life. Niar (1993) reported that shelled kernels are dried in oven at 80 to 90°C. Process took about 6 to 12 hours depending upon kernel and type of oven used. Srivastava and Kumar (1994) reported that sensory evaluation or evaluation of acceptability of final product is final operation in quality control. In sensory evaluation sensory properties such as appearance, texture and flavour that affect palatability of food are judged.

■ METHODOLOGY

Whole kernel recovery :

The cashewnut variety ‘Vengurla-4’ was selected for the

experiment. For each treatment 0.5 kg nuts were taken containing approximately 75 to 80 in numbers. Various combinations of pressure and time selected are given in Table A.

Sr. No.	Treatments	Steaming pressure, psi	Steaming time, min.
1.	T ₁	10	10
2.	T ₂	10	15
3.	T ₃	10	20
4.	T ₄	15	10
5.	T ₅	15	15
6.	T ₆	15	20
7.	T ₇	20	10
8.	T ₈	20	15
9.	T ₉	20	20

Steamed nuts after spreading for 16 to 24 hr were taken for shelling on manually operated shelling machine by skilled labour. Whole and split kernels were weighed on electronic weight balance and per cent whole kernel recovery was calculated by:

$$\text{Per cent whole kernel recovery} = \frac{\text{No. of whole kernels obtained}}{\text{Total no. of kernels shelled}} \times 100$$

To determine optimum treatment based on whole kernel recovery R.B.D. analysis was carried out. Since there were two factors each with three levels, analysis of the data was also subjected to 3² factorial experiments. The nine treatments were replicated for three times.

Drying characteristics :

The 20 g sample of shelled kernels was dried in hot air convection dryer at 70°C for 5 hours. After every 15 minute the representative sample was weighed for calculation of moisture loss. The moisture content (M.C.) was determined as,

$$\text{M.C. (d.b.)} = \frac{W_1 - W_2}{W_2} \times 100$$

where, W₁ = weight of wet sample, g
W₂ = weight of bone dry sample, g

The drying curves were plotted on the basis of observations. These curves resulted in initial moisture content (M₀) and equilibrium moisture content (M_e). Thus moisture ratio was calculated (Geankoplis, 2000).

$$\text{M.R.} = \frac{M - M_e}{M_0 - M_e} = e^{-k\theta}$$

where, M = Moisture content at any time (db)
M₀ = Initial moisture content (db)

M_e = Equilibrium moisture content (db)

M. R. = Moisture ratio

θ = Duration, min

k = Drying constant, min⁻¹

Effect of steaming on drying was analyzed on the basis of drying constant k.

Sensory evaluation :

Sensory evaluation of different organoleptic properties namely colour, flavour, texture and etching to throat were carried out by panel of 11 judges of different age groups and food habits on the basis of 9 point hedonic scale. The ranks were determined from the scores given by the judges. On the basis of ranks, Krushal- Wallis test was conducted and the value of 'H' was calculated with the following formula: (Freund and Walpole, 1987)

$$H = \frac{12}{n(n+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 3(n+1)$$

where, H = Rank

R = Value of observations

n = Number of observations

k = Total population.

The calculated 'H' values were compared with the standard value 15.51 to determine the significance of colour, flavour, texture and etching to throat among the treatments.

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

Effect on whole kernel recovery of cashewnut :

Table 1 indicates that as pressure goes on increasing per cent whole kernel recovery increased up to certain point and then it decreased. At 10 psi pressure the per cent whole kernel recovery increased with steaming time. But at higher pressure values this does not hold true. The highest average whole kernel recovery was 90.08 per cent in treatment T₇ while the lowest recovery was 46.31 per cent in treatment T₁.

In treatment T₇ exposure of steam to the nuts at 20 psi pressure and time of 10 minutes was optimum to get better detachment of kernel from shell inside the nut. Also the hardness of the kernels was such that the blades were neither penetrating fully into the kernels nor it was hard to shell.

Statistical analysis :

The results of RBD analysis are tabulated in Table 2 and 3. The RBD analysis reveals that nine treatments differ significantly from each other. The highest per cent 90.08 was observed from treatment T₇ was at par with T₈, T₉, T₄ and T₅ and highly significant with treatments T₁, T₂, T₃ and T₆.

From the 'F' value calculated it revealed that effect of

pressure was significant. Pressure affects significantly both with linear and quadratic models. As 'F' value for time was very small it showed that effect of time was non significant. Time in both linear and quadratic way was found to be non significant. But combination of pressure along with time gives significant effect on per cent whole kernel recovery.

As factors were quantitative, the analysis of data was

carried out by using 3² factorial experiment (Montgomery, 1996). This analysis revealed that effect of factor 'pressure' for both linear and quadratic models was significant but effect of factor 'time' was non significant.

As factors were quantitative different mathematical models were developed. These models are as follows :

Let, Y- Per cent whole kernel recovery

Table 1 : Observation on average whole kernel recovery and drying parameters

Sr. No.	Treatments	Average whole kernel recovery, %	Exponent 'B'	Equilibrium moisture content (db), %	Drying constant, min ⁻¹
1.	T ₁	46.31	0.0022	4.568	0.0137
2.	T ₂	58.16	0.0033	3.252	0.0129
3.	T ₃	64.88	0.0022	4.843	0.0451
4.	T ₄	85.24	0.0024	4.194	0.0135
5.	T ₅	79.52	0.0046	2.217	0.0352
6.	T ₆	75.20	0.0022	3.843	0.0144
7.	T ₇	90.08	0.0028	3.748	0.0136
8.	T ₈	83.19	0.0030	3.847	0.0361
9.	T ₉	80.84	0.0030	3.955	0.0146

Table 2 : Analysis of variance of cashew nut processing parameters

Parameters	F calculated	F tabulated	Result
Replication	***	**	
Treatment	11.760	2.59	Significant
Pressure	39.260	3.63	Significant
Pressure linear	66.400	4.49	Significant
Pressure quadratic	10.110	4.49	Significant
Time	0.0034	3.63	Non Significant
Time linear	0.0047	4.49	Non Significant
Time quadratic	0.0021	4.19	Non Significant
Pressure x Time	3.9070	3.01	Significant

Table 3 : Mathematical model for cashew nut processing parameters

Linear model for 'pressure'			
Y = 31.338 + 2.285 P**	S. E. (pressure) = 0.4701 (** highly significant)	F = 36.105 R ² = 0.5909	One unit increase in pressure increases whole kernel by 2.285 units.
Quadratic model for 'pressure'			
Y = -47.06 + 14.11P** - 0.376 P ² **	S. E. (pressure) = 4.44 S. E. (pressure ²) = 0.147	F value = 25.294 R ² = 0.678	Unit increase in pressure increases whole kernel recovery by 14.11 units. Optimum pressure (maximum shelling percentage) obtained was P = 18.76 psi
Linear model for 'time'			
Y = 31.69 - 0.023 T ^{NS} + 2.825 P**	S. E. (Time) = 0.479	S. E. (Pressure) = 0.479	Effect of time was non-significant.
Quadratic model for 'time'			
Y = -45.56 - 0.1894 T + 0.0055 T ² + 14.11 P* - 0.376 P ² *	S. E. (Time) = 4.64	S. E. (Pressure) = 4.64	Effect of time was non-significant because of difference between two times intervals was very small.
Quadratic model for 'pressure' and 'time'			
Y = -108.13 + 3.982 T + 0.0055 T ² + 18.286 P* - 0.376 P ² * - 0.2781 (P x T)*	S. E. (Time) = 4.22 S. E. (Pressure) = 4.22	S. E. (Pressure X Time) = 0.093	Linear value of pressure, quadratic value of pressure and pressure-time combination was significant.

P- Pressure
T- Time.

Effect of steaming on drying :

Kernels obtained from all treatments were dried at 70 °C for 5 hours. The drying curves of moisture content versus drying time, drying rate versus drying time and moisture ratio versus drying time were plotted for each treatment to study the effect of steaming. Table 1 represents the data collected in nine treatments for exponent B, equilibrium moisture content and drying constants.

It was observed that initial moisture content of about 9 % decreased to about 4 % during 5 hours. The following exponential model was fitted for data.

$$Y = Ae^{-Bx}$$

where A and B are constants.

Increase in exponent B value represents reduction in drying time. The value of exponent B increases with increase in steaming pressure. Increase in value of B indicates faster drying. With an increase in time, firstly there is rise in value of exponent B, but thereafter it decreased showing a peak for time value of 15 minute steaming time; which may be considered as optimal value of time for drying. It should be noted that exponent B does not show much variation in all nine treatments. Thus steaming parameter in all treatments does not affect nature of drying prominently.

The drying rate decreased drastically in initial 30 to 45 minutes. Later on drying rate showed variation with wavy profile. Wavy nature of drying rate was due to faster rate as layer exposes to drying and then reduces drying rate. The observations revealed that there is no consistent effect of pressure. Fifteen (15) minute steaming times treatments gave lower equilibrium moisture content values and showed better drying. The values of drying constants showed no much significant effect of pressure on them. It could be observed that treatment T5 of 15 minute steaming gave high values of

drying constant as 0.0352 and treatment T8 of 20 psi gave 0.0361 min⁻¹ value. At the same time, steaming time of 15 minute with low-pressure value gave least drying constant as 0.0129 min⁻¹.

Effect on sensory properties of cashew kernel :

Table 4 revealed in the average ranking of sensory properties.

The treatments differed significantly for color and texture, as 'H' values were higher than standard value 15.51. The treatments were non significant for flavour and not etching to throat properties as 'H' values were lower than standard value 15.51. The treatment T₅ was liked most by judges while T₉ was of most disliking for the colour and not etching to throat property. The flavour and texture of T₈ was favored most while T₁ was most disliked. Statistically the treatment T₈ was accepted at par with treatment T₅ with ranks 3.66 and 3.78, respectively followed by the treatments T₄ and T₇ with ranks 4.55 and 4.89. The extreme treatments T₁ and T₉ were least accepted.

Conclusion :

- The optimum steam pressure and steaming time were found to be 20 psi and 10 minutes, respectively for whole kernel recovery.
 - The mathematical model gave the optimum pressure 18.76 psi for maximum shelling percentage.
 - Treatment with 15 psi and 15 minute steaming time gave better results of drying with high exponent B value, lowest equilibrium moisture content and high drying constant for drying.
 - The sensory study concludes that among treatments colour and texture varies significantly while flavour and not etching to throat property varies non-significantly.
- Considering all aspects, steam pressure 20 psi and exposure time 15 minutes was found to be most suitable. It resulted in 83.19 per cent whole kernel recovery, accepted

Table 4 : Average ranking for sensory evaluation

Treatments	Color	Flavor	Texture	Not etching to throat
T ₁	5.82	6.00	7.45	5.00
T ₂	4.14	4.95	6.50	6.40
T ₃	4.14	5.50	6.36	5.67
T ₄	3.50	4.68	5.18	5.33
T ₅	2.63	4.41	5.06	3.98
T ₆	6.23	5.73	5.09	5.77
T ₇	6.27	4.95	3.83	5.48
T ₈	4.27	3.90	3.17	4.13
T ₉	8.00	5.22	4.97	7.01
H value =	33.2242	5.0484	24.5576	11.6000
Level of significance	Significant	Non-significant	Significant	Non-significant

as best treatment sensory evaluation and its drying behaviour were good.

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