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Research Article

EFFECTS ON QUALITY DURING INFRARED AND HOT AIR CONDITIONING OF CASHEW KERNELS

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Abstract- This study was undertaken to evaluate the effects of infrared conditioning of raw cashew kernels in terms of changes in properties and its comparative sensory analysis by fuzzy logic vis-a-vis hot air conditioning by electric tray dryer and conventional borma dryer. Changes in proximate composition were studied along with other properties like colour and microstructure changes. Proximate composition analysis showed that only moisture content varied significantly with raw cashew kernel for different conditioning methods (1% level of significance). Colour properties were found to vary with conditioning time. Microstructure analysis revealed that longer duration hot air conditioning treatment had more pronounced influence on kernel texture than short duration IR conditioning. Results of sensory evaluation study depicted that the acceptability of infrared conditioned cashew kernels were much similar to hot air and borma dryer conditioned cashew kernels and had good consumer acceptability.

Keywords- Cashew kernel, Conditioning, Infrared, Properties, Sensory evaluation by fuzzy logic

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Introduction

In cashew nut processing, conditioning is done before peeling to make the shelled cashew kernel peel fragile, so that easy peeling could be done without damaging the edible kernel. For efficient peeling, moisture content of kernels is reduced from 6 to 3% during conditioning [4]. Conventional conditioning is done by exposing the cashew kernels to 70 °C for a period of 6-7 hours in borma dryers, followed by overnight cooling under normal room conditions [4, 5]. Hot air generated by burning fuel wood or cashew shells or both, are used for conditioning operation in borma dryer, causes environmental pollution. Environmental pollution caused during the hot air conditioning operation [16] by burning cashew shells and other fuel sources are 150 mg Nm-3 at 4% CO_2. Though individual processing unit's effect is less but summed up effects of all cashew nut processing units on environment has deep impact. Report published on Comprehensive Industry Document for Cashew Seed Processing Industries (COINDS/75/2007) by Central Pollution Control Board, Ministry of Environmental & Forest, Government of India, stated that flow rate of flue gas emission during hot air conditioning is 186-996 NM3/h where temperature varied between 190 to 352 °C. Average composition of flue gas emitted from cashew processing plant contains SO_2: 10-48 mg/ NM^3, NO_x: 55-146 mg/ NM^3, OH: 0.4-0.8 with CO_2 percent 1.0-2.7%. In order to make conditioning rapid and without much environmental impact, infrared thermal treatment was tried as alternate to conventional hot air conditioning.

Infrared heating is more advantageous compared to conventional heating, due to reduced heating time, uniform heating, reduced quality losses, versatile, simple and compact equipment, and significant energy saving [21]. Afzal and Abe [1] from their study concluded that using far infrared energy to dry rough rice resulted in much faster drying than by convection.

Conditioning of cashew kernels by infrared heating had been optimized with response surface methodology by Hebber and Ramesh [9]. Hebber and Rastogi [8] reported on mass transfer during infrared conditioning of cashew kernels, where mechanism of water transport was investigated. Though some literatures are available regarding changes occurring during infrared heating of food products, but no research literature was found on the changes in properties of cashew kernels undergoing infrared thermal treatment. Major work had been done regarding changes in moisture content of cashew kernels during infrared processing. Beside this, no study was found on sensory evaluation of conditioned cashew kernels by infrared method of conditioning.

Sensory evaluation is one of the most important factors that decides the final acceptance or rejection of the product by consumers [25]. Problems associated with sensory evaluation are, often the outcomes of the evaluation are imprecise and in linguistic form containing ambiguity and vagueness. For analyzing the results of the outcome of sensory evaluation, Fuzzy logic was used which is a tool for analyzing these type of vague and imprecise data [6].

The objectives of this study was to evaluate the effects of infrared conditioning treatment on cashew kernel properties in terms of proximate compositional analysis, colour properties, microstructure and sensory evaluation by fuzzy logic and compare it with conditioned cashew kernel properties.

MaterialsandMethods

Procurement of raw materials

Raw cashew nuts were procured from Agricultural Farm in Kharagpur, West Bengal (India). Raw nuts were roasted and shelled manually. Shelled cashew kernels were covered with thin light brown coloured testa layer or peel. This shelled unpeeled cashew kernels were subjected to different conditioning treatments, i.e. infrared conditioning and hot air conditioning treatment by conventional borma dryer and electric hot air dryer to make the peel fragile.

Infrared conditioning

Infrared conditioning was done by using Infrared bulb [Philips, 230 V & 375 W], which was kept enclosed in a covered case at 160 °C for time duration of 8 minutes, as shown in [Fig-1]. This time temperature combination was established by running preliminary trials at different time temperature combination. Electrical variac was used to vary the voltage supply of the infrared lamp.

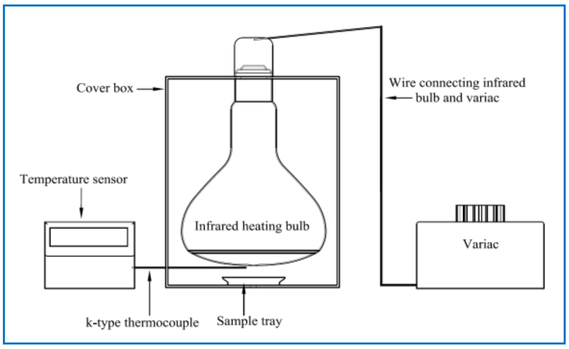

Fig-1 Infrared conditioning set up

Hot air conditioning
Hot air conditioning was done in electric powered hot air re-circulatory tray dryer (Rotex Trasnmission, Maharashtra), as shown in [Fig-2].

Fig-2: Electric hot air dryer

Conditioning by borma dryer
Hot air conditioning was done in conventional borma dryer (Jhargram, West Bengal), which generates hot air by burning fuel woods and cashew shells, as shown in [Fig-3].

Fig-3: Borma dryer for cashew kernels

Quality evaluation
After conditioning by hot air and infrared method, the kernels were cooled under room temperature (27-30 °C, RH 75-80%). Cooled kernels were peeled manually and subjected to various analyses.

Proximate composition analysis
Raw cashew kernel and two differently conditioned cashew kernel samples were pulverized and used for determining a whole set of chemical properties such as moisture content, crude fat, protein, total dietary fibre and ash. These properties were determined using standard AOAC methods. All analyses were performed in repeated trails and reported [3].

Colour properties
Colour values were estimated in terms of L*, a* and b* values with the help of Colourimeter (CM-5, Konica Minolta). Experiments were conducted to study the colour change in raw cashew kernels undergoing infrared heat treatment for different levels of time period. Total colour change (ΔE) was determined by [Eq-1].

$$\Delta E = \sqrt{(L^*_0 - L^*_t)^2 + (a^*_0 - a^*_t)^2 + (b^*_0 - b^*_t)^2}$$ [Eq-1],

where,
L^*_0 and L^*_t are the initial and final brightness values of the sample
a^*_0 and a^*_t are the initial and final redness values of the sample
b^*_0 and b^*_t are the initial and final yellowness value of the sample.

Non-enzymatic browning was seen while infrared conditioning of cashew kernels. Browning index (BI) was determined according to the method adopted by Hebbar & Ramesh [9], Maskan [14] and Swain et al. [26] which is shown in [Eq-2] and [Eq-3].

$$BI = \frac{100(x - 0.31)}{0.17}$$ [Eq-2]

$$x = \frac{a^* + 1.75L^*}{5.645 + a^* - 3.012b^*}$$ [Eq-3]

Microstructure analysis
For studying the micro-structural changes due to different methods of conditioning, scanning electron microscope (JSM5800, JEOL Japan) was used [15, 28]. Before scanning electron microscopic analysis, the samples were gold coated by Enton Vacuum, inc., Desk I Tungsten filament, Energy - 20 kV, at 50 micrometer wavelength. Samples were numbered as follows:
Sample 1: Raw cashew kernels
Sample 2: Hot air conditioned cashew kernels in electric dryer
Sample 3: Infrared conditioned cashew kernels

Images of the samples were taken under 500X and 1000X magnification, to observe the microstructure of the sample.

Sensory data analysis using fuzzy logic
Conditioned and peeled edible kernels were subjected to sensory evaluation by a panel of 61 judges selected from students and staff members at IIT Kharagpur, who were familiar with the sensory properties of cashew kernel. For sensory evaluation, three cashew kernel samples were considered, which are numbered as follows:
Sample 1: Hot air conditioned cashew kernels by electric dryer
Sample 2: Infrared conditioned cashew kernels
Sample 3: Hot air conditioned cashew kernels by conventional borma dryer

Ratings of samples were done by qualitative manner, i.e. by tasting the sample and selecting any one of the linguistic parameters, like "Not Satisfactory", "Fair", "Medium", "Good" and "Excellent" [6]. The score cards containing sets of observations by the sensory panel were summed up and were subjected to Fuzzy logic analysis.

Ranking of three samples of cashew kernels and their quality attributes were carried out using triangular fuzzy membership distribution function according to the fuzzy logic method as described by Das [6]. Quality attributes and sensory scores obtained from the judges were transformed in triplets. Triplets are the sensory scales, in triangular fuzzy membership functions. These triplets were used for determination of similarity values, which were required to rank the samples according to their sensory properties. Steps for sensory evaluation by fuzzy logic were given below:

a. Determining triplets of overall sensory scores of cashew kernel samples
b. Estimating membership functions on standard fuzzy scale
c. Computing overall membership functions of sensory scores on standard fuzzy scale
d. Determining similarity values of cashew kernel samples

After determining the similarity values for each samples for four quality parameters (i.e. colour, flavour, taste and mouth feel), the highest similarity value was selected and the corresponding sample was ranked as the best quality sample, followed by the other two samples. This method of sensory evaluation of food samples with the help of fuzzy logic approach had been applied successfully by a number of researchers. Fuzzy logic analysis was first introduced by Zadeh [30], which was adopted for sensory data analysis for mango drinks [11], dahi [22], instant green tea powder [24], bread prepared from composite millet flours [23] and channa podo [17].

Statistical analysis

Experiments were conducted in trials and reported as mean ± standard deviation. The effects of different conditioning treatments on proximate composition of cashew kernels were analysed using one-way analysis of variance (ANOVA). F value was calculated at 1% level of significance.

Results and Discussion

Proximate compositional analysis

Proximate composition of raw, hot air conditioned and infrared conditioned cashew kernels are shown in [Table-1].

Table-1 *Compositional analysis of three different treatments*

Composition (%)	Raw	Hot air	IR
Moisture	7.34±0.03^{a}	3.37±0.17^{b}	2.11±0.33^{c}
Fat	48.77±0.87^{a}	47.85±0.66^{a}	48.10±0.63^{a}
Protein	37.27±1.38^{a}	36.92±1.02^{a}	36.94±1.04^{a}
Ash	2.03±0.60^{a}	2.14±0.99^{a}	2.16±0.85^{a}
Crude fibre	3.37±0.42^{a}	3.57±0.23^{a}	3.52±0.38^{a}

Values are given as mean ± standard deviation and the different letter within each row are significantly different (p<0.01)

Proximate composition of raw cashew kernels was found to be similar with the proximate composition of raw cashew kernels as reported by Akinhanmi and Akintokun [2]. From [Table-1], it can be said that there was significant change in moisture content during hot air and infrared thermal treatment. Hebbar and Rastogi [8] and Fasina et al. [7] reported about moisture loss during infrared processing. Except moisture content from [Table-1], it can be seen that there were no changes in other proximate composition of cashew kernels, due to different conditioning treatments.

Similar findings were reported by Padmashree et al. [19], during infrared processing of mung bean seeds, where no significant changes in crude protein, crude fat and crude fibre contents of mung bean seeds, was observed with comparison to raw samples. Arce-Arce et al. [3] reported no changes in crude fat, ash and crude fibre content in proximate composition of common bean seeds flour undergoing infrared heating, though there was a significant change in protein composition. Fasina et al. [7] stated no effects in the concentration of starch and proteins during infrared heating of legume seeds.

Colour changes during conditioning

During infrared conditioning, colour change was observed. L*, a* and b* was determined and was found that infrared conditioning for more than 8 minutes lead to discolouration and burning of cashew kernel sample. There is a reduction in L* value with increase in infrared conditioning time. Browning index (BI) and Total colour change (ΔE) determined from [Eq-1, 2 and 3] was also found to be increasing with infrared conditioning time, as shown in [Fig-4 and 5].

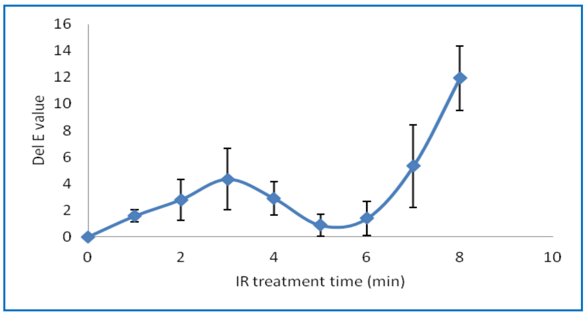

Fig-4 Change in colour value with infrared conditioning

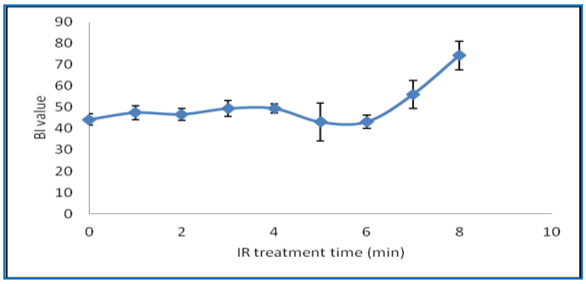

Fig-5 Infrared treatment time vs. BI value

It could be seen from [Fig-4 and 5] that after 4th min, there was reduction in both ΔE and BI values. This reason was demonstrated in the work of Nowak and Lewicki [18] where infrared heating of apple slices was studied and it was found that with increase in infrared treatment time, luminance increased because of removal of water due to drying and the space occupied by water getting replaced by air, hence a porous structure was formed that altered light absorption and scattering causing dry material look lighter in colour, causing lowering of ΔE and BI values. Prolonged thermal treatment caused colour change (ΔE) and increase in b value due to non-enzymatic browning [18, 13, 31].

Microstructure analysis

Microstructure of raw, hot air conditioned and infrared conditioned cashew kernel samples were viewed under scanning electron microscopy and SEM images were presented at 500X and 1000X magnification, as presented in [Fig.-6].

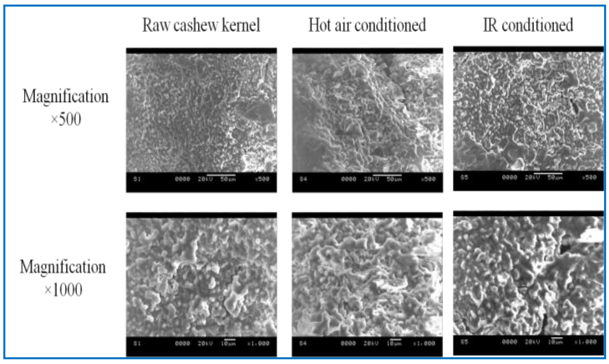

Fig-6 SEM images of cashew kernels

It could be seen that the hot air treated cashew kernel's microstructure is different from that of the microstructure of infrared conditioned and raw cashew samples. Hot air conditioning though had been done at a lower range of temperature (70 °C) but have a longer treatment time of 6-7 hours. Although it has been reported that, high temperature causes deformation in microstructure of the sample [27, 10] but for this study, it was found that due to extensive conditioning period during hot air conditioning, changes in microstructures are more compared to that of short time infrared conditioning treatment. Infrared conditioning requires less conditioning time. Changes in microstructure are less when short time conditioning treatment like infrared conditioning is given, instead of long duration hot air conditioning. Witrowa-Rajchert and Rząca [27] reported that apple slices which were dried by conventional hot air drying differs significantly in structural characters from the apples dried using infrared assisted convective method of drying. It was further reported that greater shrinkage occurred in apple slices undergoing hot air drying then infrared assisted hot air drying.

Sensory evaluation using fuzzy logic

Sensory scores as given by the panel of judges in score card was summed up and presented in [Table-2].

Table-2 *Sensory score sum total*

Sensory quality attributes	Sensory scale factors				
	Not satisfactory	Fair	Medium	Good	Excellent
Colour					
Hot air conditioned	0	6	9	43	3
IR conditioned	0	12	9	37	3
Borma dryer conditioned	6	15	24	16	0
Flavour					
Hot air conditioned	0	9	12	37	3
IR conditioned	3	6	27	25	0
Borma dryer conditioned	6	15	18	22	0
Taste					
Hot air conditioned	0	15	12	28	6
IR conditioned	0	0	27	34	0
Borma dryer conditioned	6	15	18	16	6
Mouth feel					
Hot air conditioned	0	18	12	22	9
IR conditioned	0	24	18	16	3
Borma dryer conditioned	15	21	12	10	3

Triplets for overall sensory scores of conditioned cashew kernels:

To determine triplets for overall sensory scores, triplets of sensory scores of three different cashew kernel samples were determined, which are coded as S1C = sample 1 colour. Similarly F = Flavour, T = Taste and M = Mouth feel. Numeric value 1, 2 and 3 represents Sample number 1, 2 and 3 respectively.

S1C = (67.62, 25.00, 23.77)
S1F = (63.93, 25.00, 23.77)
S1T = (60.25, 25.00, 22.54)
S1M = (59.02, 25.00, 21.31)

S2C = (62.70, 25.00, 23.77)
S2F = (55.33, 23.77, 25.00)
S2T = (63.93, 25.00, 25.00)
S2M = (49.18, 25.00, 23.77)

S3C = (45.49, 22.54, 25.00)
S3F = (47.95, 22.54, 25.00)
S3T = (50.41, 22.54, 22.54)
S3M = (35.65, 18.85, 23.77)

Triplets for sensory score of quality attributes were determined. These values represent all judges' preference to importance of quality towards each sensory attributes. Triplets were represented by codes QC, QF, QT and QM.

QC = (54.92, 25.00, 22.54)
QF = (61.47, 25.00, 22.54)
QT = (84.01, 25.00, 13.52)
QM = (76.23, 25.00, 16.39)

Relative weightage of each quality attributes were determined as stated in materials and methods and stated below.

QC rel= (0.20, 0.09, 0.08)
QF rel = (0.22, 0.09, 0.08)
QT rel = (0.30, 0.09, 0.05)
QM rel= (0.27, 0.09, 0.06)

Triplets associated with overall sensory scores of cashew kernels were determined as presented below.

SO1 = (62.19, 47.67, 39.88)
SO2 = (57.71, 45.61, 40.07)
SO3 = (44.82, 37.75, 36.10)

Values of overall membership function of sensory scores for Sample 1, 2 and 3 on standard fuzzy scale was calculated, which is shown below.

B1 = (0.00, 0.11, 0.32, 0.53, 0.74, 0.95, 0.80, 0.55, 0.30, 0.05)
B2 = (0.00, 0.17, 0.39, 0.61, 0.83, 0.94, 0.69, 0.44, 0.19, 0.00)
B3 = (0.08, 0.34, 0.60, 0.87, 0.85, 0.58, 0.30, 0.02, 0.00, 0.00)

Calculated similarity values for cashew kernel samples have been shown in [Table-3].

Table-3 *Similarity values of sensory scale*

Scale factors	Electric dryer conditioned	Infrared conditioned	Borma dryer conditioned
Not satisfactory	0.02	0.03	0.10
Fair	0.24	0.31	0.57
Satisfactory	0.66	0.74	**0.93**
Good	**0.83**	**0.80**	0.53
Very Good	0.44	0.35	0.07
Excellent	0.07	0.03	0.00

From [Table-3], the maximum similarity values for the three samples were 0.83 (Good) for hot air conditioned cashew kernels by electric dryer (i.e. Sample 1), 0.80 (Good) for infrared conditioned cashew kernels (i.e. Sample 2) and 0.93 (Satisfactory) for hot air conditioned cashew kernels in conventional borma dryer (i.e. Sample 3). Based on these findings, the sensory qualities of three cashew kernel samples were ranked as follows: Sample 1 > Sample 2 > Sample 3. This study suggests that the sensory quality of infrared conditioned cashew kernels were similar to that of conventionally and hot air conditioned cashew kernels. Early work had been reported on optimization of infrared conditioning of cashew kernels based on colour and other parameters [10]. Beside this, sensory properties of infrared processed foods in comparison of conventionally processed foods were considered acceptable by several researchers (12, 29, 20 and others).

Conclusion

This study investigated about the changes occurring in cashew kernels during infrared conditioning and comparing the properties with conventionally conditioned cashew kernels. From proximate compositional analysis, it was found that, other than moisture content no significant changes were found in proximate composition ($p<0.01$) of cashew kernels. Colour properties were studied in terms of L*, b* and a* values and Total colour change (ΔE) and Browning index (BI) was calculated, which was found to be increasing with conditioning time. After 4 min there was reduction in ΔE and BI values. Further conditioning caused rise in ΔE and BI values. Microstructure study concluded that, longer duration conditioning treatment like hot air condition changes the microstructure of cashew kernels more than short time infrared conditioning method. Sensory evaluation by fuzzy logic established the fact that sensory attributes of infrared conditioned cashew kernels were similar to that of hot air conditioned and conventionally conditioned cashew kernels and was found to be acceptable by the sensory evaluation panel of judges. Future research studies may be conducted on changes in bioactive compounds composition in cashew kernels during infrared conditioning.

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Conflict of Interest: None declared

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