DISINFESTATION OF CASHEW NUTS BY INFRARED TECHNOLOGY

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Abstract

The impact of Infrared (IR) treatment on the disinfestation of cashew nuts is the main objective of the study. Cashew nuts are IR-treated at different temperature ranges by correlating the belt speeds to check the infestation (Tribolium and larvae). The trials were taken from temperatures ranging from 50℃ to 250℃ in four different zones, belt speeds at 1m/min, 2m/min, and 3m/min, and throughput was set from 200kg/hr to 800kg/hr. The moisture, Scorched wholes, Browns, Broken, and infestation are the parameters that were optimized. Based on the percentage of defects and infestation the cashew nuts treated at a temperature of 180℃ and belt speed of 2m/min were fit for packing. The optimum moisture obtained at this temperature and speed was observed as 3.92±0.32%, the optimum percentage of scorched wholes was 5.48±0.73% and the broken percentage was obtained as 5.53±0.58% which was all in accepted specifications. The packed samples were kept for shelf life studies to analyze the infestation in the future so as to validate the IR device. After analyzing the shelf life samples where no infestation was found, the temperature and the belt speed were concluded as 180℃ and 2m/min respectively since this meets the required production throughput of 600kg/hr.

Keywords: Belt speed, Broken, Browns, Cashew nuts, Infrared treatment, Infestation, Moisture, Scorched Wholes (SW), Temperature, and Throughput.

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Introduction

Cashew nut: Cashew has become a food for munching and is also eaten as an appetizer in day to day life. India is the largest producer of cashew and has a good foreign exchange. The cashew is an evergreen tree with a large range of moisture variations. The cashew tree is a common Brazilian plant that grows along the coast, from the Amazon to the Northeast.

It is found throughout the world's tropical areas, including Mozambique, Tanzania, Kenya, Guinea-Bissau, Indonesia, Thailand, Vietnam, and India. The shell, coat, and nut are the three parts of the cashew nut. A nut can weigh anywhere from 2g and 30g, with an average weight of about 7g. The nut, which is made up of two ivory cotyledons, weighs between 28% and 30% of the total weight of the nut. The film, or coat, compensates around 3% of all the weight. The nut's shell contains an acidic fluid or sap that severely irritates the skin and results in painful blisters. The ex-albuminous seeds have a tiny embryo, two big, white cotyledons, and a reddish-brown Testa. They must be boiled or roasted in order to remove the volatile oil before being opened or shelled because they are inedible when raw.

Cashew Processing: The steps involved in cashew processing are cooking, sizing, conditioning, shelling, peeling, grading, fumigation and packing. Cashew has different grades, in which cashew as a whole are mostly exportable. The different grades of cashew as a whole are W180, W240, W320, W450 etc. Along with these wholes Fancy Splits (FS) pieces are also exportable. The cost of the cashew as a whole is more when compared with the cost of the pieces. Maintaining the wholes without becoming broken is a tough challenge for the production.

Infestation of cashew nut: The infestation is major problem in the cashew industry. The cashew is being attacked by more than fifty species of insect pests throughout the world. Not only during the cultivation is the infestation, also caused after the processing and packing of the food commodities. Most common type of insect which infect the cashew nuts during the processing is *Tribolium castaneum* which has a huge rate of reproduction. It is a global pest of stored goods, especially food grains, and a model organism for studies in ethology and food safety. The infestation of cashew nut decreases the shelf life of the nut. The red flour beetle attacks stored grain and other food products like biscuits, cereals, flour, beans, nuts and pasta causing loss and damage to the food products.

Different methods of disinfestation: Different disinfestation techniques came into play for the removal of live infestation. These may be either fumigation or thermal techniques. Fumigation was done by using various fumigants (like Aluminum Phosphine, Methyl Bromide etc.). Since fumigation was not 100% efficient and requires a long time period for the reactants to react, thermal techniques of disinfestation came into existence. The thermal techniques most commonly used are Infrared treatment (IR) and Microwave treatment. Pest infestations in food and other stored goods are avoided by using fumigants.

Fumigant treatment may have a variety of effects on the commodity's quality. The product may contain fumigant residues that have not changed. Changes in flavor, taste, odor, nutritional value, or processing attributes can come from the individual chemical components of the commodity reacting with the fumigant, which can also modify other aspects of the commodity's chemical or physical properties. The main fumigants used to treat cereals, vegetables, and fruits include ethylene dibromide, ethylene dichloride, carbon tetrachloride, phosphine, and ethylene oxide. Short time microwave treatment is a potential replacement for other existing quarantine techniques since it has a number of benefits, including faster treatment times, higher quality retention, and less energy consumption. In the past few years, IR radiation has been widely used in the food sector for a variety of thermal processing procedures, including dehydration, frying, and pasteurization.

Other food processing applications, such as roasting, frying, broiling, heating, and cooking meat and meat products, soy beans, cereal grains, cocoa beans, and nuts, have also shown the value of IR heating. Pinto beans' rehydration rate and degree of swelling were found to be enhanced by IR heating, although their cooking time rose noticeably. Without lowering the quality of the food, bacteria can be surface pasteurized using infrared heating.

An efficient heat treatment called IR disinfestation leaves no chemical residues while being reasonably simple to perform.100% disinfestation is achieved by IR method where the cashew kernels are exposed to high temperature ranges with supply of electric energy.

Materials and methods

Cashew Process flow for processing of Raw Cashew Nut:

The different steps involved in the processing of cashew nut are as follows:

Receiving of Raw Cashew Nut
The Raw Cashew Nut is the essential raw material for obtaining the whole cashew nut. Raw Cashew Nut was procured from various countries like Nigeria, Ivory Coast, Burkina Faso, India, etc. Each bag weighs about 80kgs of Raw Cashew Nut. A cutting test was initially conducted to check the parity of how much cashew would be obtained at the end of the processing. A quarantine method was developed for this process where a composite sample of Raw Cashew Nut was collected, its nut count was checked and cutting was done to check the defects.

Pre Cleaning of Raw Cashew Nut
The pre cleaning method was obtained to remove the stones and foreign matter from the Raw Cashew Nut. The mechanical pre cleaner was used for this method which contains a sieve (10mm) greater than the size of Raw Cashew Nut. The foreign matter and the stones which were smaller than the size of Raw Cashew Nut were dropped down and collected separately. The stones whose size (>26mm) were picked separately by the workers on a conveyor belt attached to the pre cleaner.

Sizing
The sizing was done to separate the different sizes of Raw Cashew Nut. The different sizes of RCN were ≤17mm, 18-20mm, 20-22mm, 22-24mm, 24-26mm and ≥26mm. The sizer consists of rotating sieve drum where the RCN get separated based on the size.

Cooking
The cooking of Raw Cashew Nut was done to reduce the moisture in shell so as to loosen the cashew shell which is attached to the cashew kernel. A cooker of 2 tones capacity was used to cook the Raw Cashew Nut at a steam temperature of 130 - 150℃ for a time of 20mins.

Resting
Resting was done to decrease the moisture in the Raw Cashew Nut so that it could be is shelled easily by decreasing the moisture in cashew nut shell. This was done for a time of 18 – 24hrs for cooling of RCN to prepare it for the shelling process.

Conditioning
It is a two-step process in which first step was drying and second step was humidification. The process was adapted to loosen the testa adhered to the kernel. The dehumidification step was done in Borma dryer where the temperature was maintained around 80℃ for 8hrs. The next step in conditioning was humidification which was done in humidifier at a temperature of 30℃ for 8hrs.

Peeling
This step was obtained to remove the testa from the cashew kernels. The results of this step were fully peeled wholes, partially peeled wholes and husk powder. The fully peeled wholes were sent to the color sorter for the separation of rotten and partially peeled wholes from fully peeled wholes.

Grading
Grading is the method of segregating the cashew kernels based on the size and count of the kernels. The different grades obtained from this step were Wholes180 (W180), Wholes 240 (W240), Wholes 320 (W320), Wholes 450 (W450), Fancy Splits (FS), and Scorched Wholes (SW) and Multigrade wholes. The nomenclature of the grades was given by counting the kernels/1lb. The cashew kernels which were named as W180 counts 160 – 180 kernels/lb., cashew kernels which were named as W240 has a count of 220 – 240 kernels/lb., cashew kernels with W320 as a name has a count of 300 – 320 kernels/lb. and cashew kernels with W450 as name has a count of 400 – 450 kernels/lb.

IR treatment
Infrared treatment was done to remove the live infestation in the cashew kernels. The presence of live infestation leads to the spoilage of cashew. The IR treatment was carried out by supplying the temperatures (100 to 190℃) and with a belt speeds of 1m/min, 2m/min and 3m/min in the machine. The extended shelf life of the goods is aided by the high temperatures' ability to destroy live insects.

Cooling
Due to the high temperatures in IR treatment the product becomes unfit for packing since it leads to bonding. Hence to decrease this bonding the cashew kernels are sent to the cooling where the temperature was maintained around 25 to 30℃ for 4 to 5hrs. After attaining the product temperature to around 30 to 35℃ the cashew kernels were sent for packing.

Packing
The packing was done in 25lbs or 50lbs pouches or tins as per customer requirement. The LDPE pouches (0.5µ) were used for the packing purpose and kept in cartons.
Cashew wholes/Cashew kernels are white/pale ivory/ light ash with characteristic shape. Along with their taste, shape and color, cashew kernels sizes are an important characteristic of quality and value. The benchmark grade is W320 which is

ivory with characteristic form that counts 300-320 kernels per pound and 660-705 kernels per Kg (according to Association of Food Industries specifications). W – 320/Grade – III are the highest in terms of availability, worldwide and most popular among cashew kernels. These cashew wholes were chosen for the trials since there was a large customer (70%) requirement for this grade. Also this grade of cashew was most commonly exposed to infestation (1 in 1000 kernels) because of stacking for a longer time due to its high production than that of the other grades.

According to Association of Food Industries (AFI) specifications, insect damage comes under the category of serious damage. It is defined as the Live or dead insects, mites in any stage of development, insect faeces or pieces, frass, webbing, burrowing, powder residue, cast larval casings, and/or signs of insects or insect activity in the packing can all cause apparent harm to the kernel.

Experimental device for disinfestation

The Infrared device experimentally designed especially for killing of insects in the food materials by maintaining the temperatures. The temperatures (100 to 190℃) are obtained by supplying certain energy of light (µV). The schematic diagram of an IR device is given below. The main components in this IR device are; a heating source (an IR lamp), a conveyor belt, a hopper, zones with heaters and temperature sensors.

The hopper was connected to a vibratory feeder which helps in uniform flow or single layer of the product. This flow helps the cashew to get uniform exposure so as to kill the insects. A single conveyor belt helps the flow of cashew through the IR device. The belt speed (1m/min, 2m/min & 3m/min) plays an important role in killing of the infestation. The regions of IR device are divided into three different zones where different temperatures (100 to 190℃) are maintained and also by maintaining the belt speed which help in the killing of insects and decreasing the defects in cashew. Temperature sensors are connected at each zone for checking the required temperature. These temperatures are controlled by a digital screen on the panel board. The material is fed through a conveyor from the SS bin to the hopper. A sensor is connected to the hopper and has an interlock with the feeding conveyor to stop the overflow of the material.

Experimental procedures

The method of IR treatment has mainly two steps: (1) Preparation of infested samples and (2) Infrared treatment of infested cashew kernels.

Preparation of infested samples: Live larvae and beetles were collected and kept in a bowl with cashew so as to increase the sufficient population to carry out different trials. Then the cashew wholes (W320) were inoculated by inserting live larvae and beetles inside the cashew wholes carefully and sealed by inserting cashew powder inside the holes. Larvae inoculated wholes were marked with “L” on both sides and beetle inoculated wholes were marked with “B” on both sides.

Infra-Red Curing Treatment of Inoculated Cashew Kernels Different trials were conducted to validate the following process and also control the machine parameters to achieve desired infestation. The common procedures for all trials were as follows.

1. The grade taken for trial wasW320/Grade - III.
2. The line throughput was set to 200 kg/h to 800 kg/h before the trial began, with only conveyors running at 1 m/min, 2 m/min, and 3 m/min speeds.
3. After setting the respective trial parameters, all the heaters were on and waited till present value reaches the desired temperatures (Refer Table 3.1). After achieving the desired temperature, the feeder was switched on to feed the cashew whole (Grade – III/W320) in IR curing machine.

4 Because they were anticipated to be the weak zones, samples injected with larvae and beetles were fed into the IR Curing machine with the product flow and close to the feeder at conveyor side corners. The inoculated samples were then taken out three minutes later, isolated, and packed in 1 kg LDPE pouches with the relevant markings, preserved for shelf life, and then examined for live infestation.

Sampling procedure and method of evaluation for defects

The defects were evaluated as per AFI specifications. The sampling procedure was done by taking 500gm samples for each trial. The defects were picked up from the 500gm sample and weighed and calculated in percentage. Same as the defects, the infestation was also noted by the number of live insects present. To know the infestation split test was conducted. The wholes which were marked with the infestation were split into two halves and checked visually for the live insects. Each trial had 10 replicates for better understanding.

$$Formula\ for\ percentage\ of\ defects = \frac{Weight\ of wholes}{Total\ weight\ of\ sample} \times 100$$

Results and discussion

Total 16 trials were taken in IR machine to obtain 100% disinfestation in cashew nuts with required

specifications i.e. Moisture (3.5 – 4%), Scorched Wholes (5.5 – 6%), Broken (6 - 7%), Browns (0 – 0.5%) and infestation (0%) before packing. To find the optimum outcomes, various iterations were taken into consideration. By considering various parameters like Infestation, Scorched Wholes (SW), Moisture, Broken and Color variation (Browns) trial – IX with a belt speed of 2m/min and at a temperature of 180℃ was finalized. The finalized trial was kept for shelf life to check for live infestation in future. Trial – IX with belt speed of 2m/min was finalized based on the output results i.e. percentage of live infestation, SW, moisture, broken and browns that were under required specifications. The trials were set down in such a way to explore the best combinations of temperatures and belt speed with required specifications of parameters.

Trials taken at belt speed of 1m/min: For a belt speed of 1m/min total of four trials were taken where all the trials which were obtained showed negative results. There was a gradual decrease observed in live infestation count (40 to 18 live Tribolium and 2 to 0 for live larvae) from the first trial to fourth trial. Though the live infestation percentage was decreasing gradually there was an increase in the percentage of defects which deviated the required specifications. The throughput obtained (200Kg/hr) was much less than the required throughput (600Kg/hr).

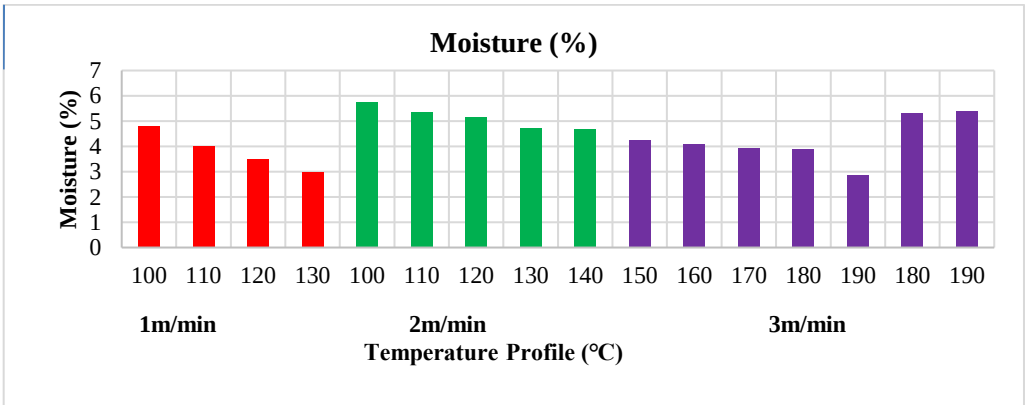
Parameters		**Required specifications**	**Obtained values**
Moisture %		3.5- 4	3
Scorched Wholes (SW) %		5.5 - 6	5.8
Broken %		6 - 7	6.2
Browns %		0 – 0.5	4.2
Infestation (Count)	***Tribolium***	0	0
	Larvae	0	18

Trials taken at a belt speed of 2m/min: The second set of trials was taken at a belt speed of 2m/min at the same temperatures as the previous trial. Since there was a gradual decrease in the live infestation count (Live larvae – 5 to 0 and *Tribolium* 48 to 0) percentage with required specifications the trial was continued above trial – IV. Total 10 trials were taken at the same speed and temperatures as that of the trial conducted at a belt speed of 1m/min. The throughput obtained (600Kg/hr) which was the required throughput capacity (600Kg/hr).

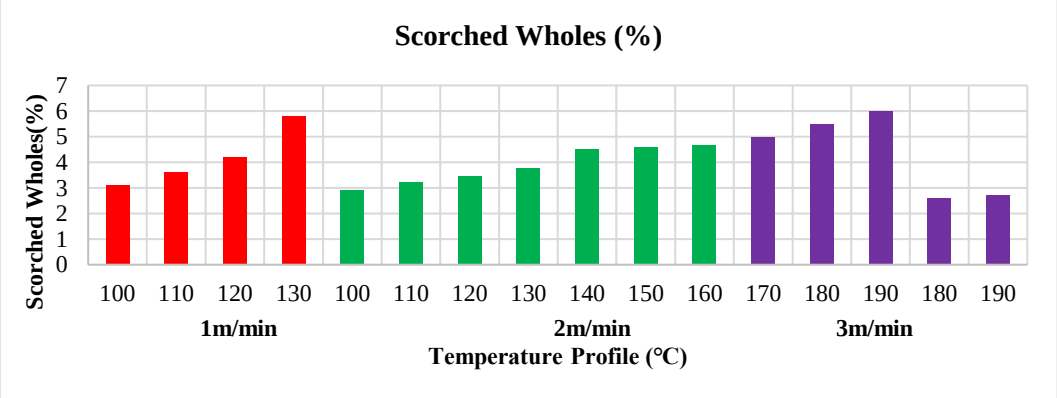
Parameters		**Required specifications**	**Obtained values**
Moisture %		3.5- 4	3.9
Scorched Wholes (SW) %		5.5 - 6	5.48
Broken %		6 - 7	5.53
Browns %		0 – 0.5	0.5
Infestation (Count)	**Larvae**	0	0
	Tribolium	0	0

Trials taken at a belt speed of 3m/min: The next set of trials were conducted at a belt speed of 3m/min at the same temperatures and parameters as that of trial – IX of belt speed 2m/min. Taking trial – IX as basis for this set of trials only the belt speed was changed from 2m/min to 3m/min. The temperatures were set as per the trial – IX (180℃) since this trial gave 100% disinfestation and also the defects were under required specifications. The trial was conducted as the previous trials but this time the exposure time for the cashew decreased due to increase in the belt speed. The increase in belt speed led to the decrease in killing of live infestation with negligible decrease in the moisture percentage. The trial was stopped since there was no change in the disinfestation percentage. Also there was no much change in the color variation (Browns).

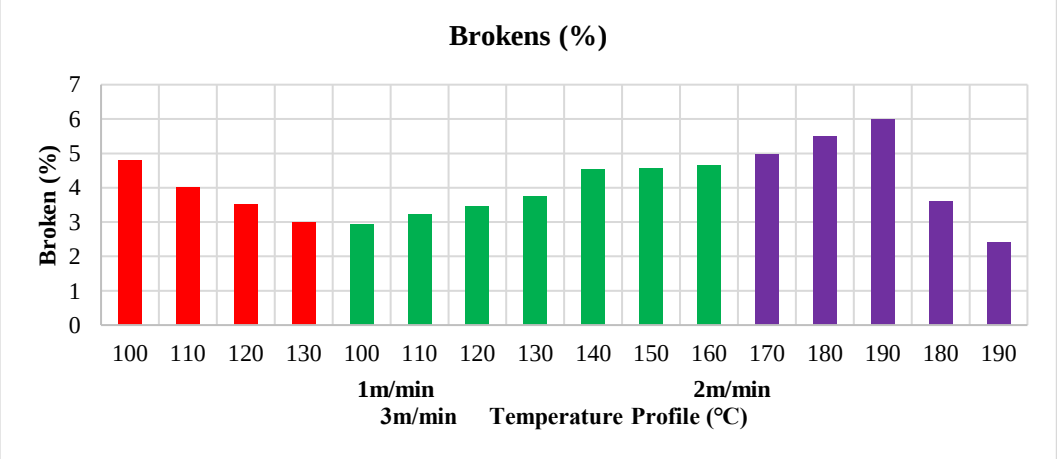
Parameters		Required specifications	Obtained values
Moisture %		3.5- 4	5.4
Scorched Wholes (SW) %		5.5 - 6	2.7
sBroken %		6 - 7	2.4
Browns %		0 – 0.5	0.5
Infestation (Count)	**Larvae**	0	0
	Tribolium	0	1



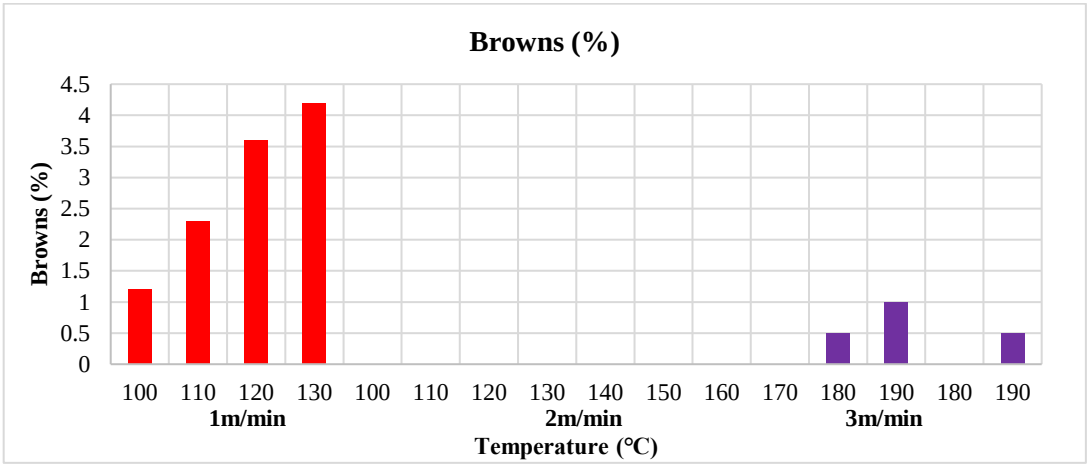
Comparison of moisture percentage at various temperatures for different belt speeds



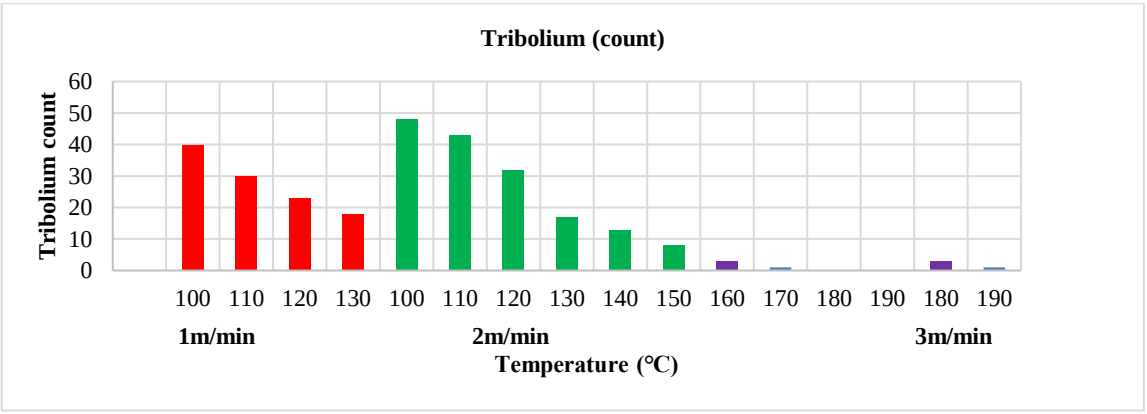
Comparison of Scorched Wholes percentage at various temperatures for different belt speeds



Comparison of Broken percentage for cashew kernels at various temperatures for different belt speeds



Comparison of Browns percentage in cashew kernels at various temperatures for different belt speeds



Comparison of *Tribolium* count in cashew kernels at various temperatures for different belt speeds

Summary and Conclusion

In the present study an attempt has been made to validate the infrared curing machine efficiency by inserting the live infestation with product, at set temperatures and to achieve killing of infestation and to standardize the throughput capacity of machine by optimizing the belt speed.

Keeping in mind the customer satisfaction and Association of Food Industries (AFI) specifications the parameters were considered for the trials. Maintaining the temperatures (100 to 190°C) and belt speeds (1m/min, 2m/min and 3m/min) the disinfestation was achieved along with the production target (600Kg/hr).

W320/Grade – III was chosen as the trail material due to its high production and customer requirement. According to the study conducted, at a belt speed of 1m/min speed there was an increase in browns and broken content due to decrease in moisture percentage which makes the cashew wholes brittle. The throughput achieved (200Kg/hr) at this belt speed was less than the required throughput (600Kg/hr). At a belt speed of 3m/min since the belt speed was increased the exposure time of cashew to heat was decreased which led to less in the disinfestation percentage though the throughput (600Kg/hr) was more than the required throughput (800Kg/hr). 100% disinfestation was achieved at an optimum belt speed of 2m/min at a temperature of 180°C (zone – I), 230°C (zone – II) and 130°C (zone –III) with the required throughput (600Kg/hr). The parameters obtained were also in the required specifications (Moisture – 3.9%, Scorched Wholes – 5.48%, Browns – 0.5% and Broken – 5.48%).

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