Controlled Microwave Technology for Disinfestations of Selected Pulses

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Abstract

The grains get spoiled or infected due to environmental changes, excess use of chemical and lack of storage houses which, results into losing their nutritional values. Therefore, it is necessary to check the nutritional status of grains time to time since the nutritional factors also depend on upon the environmental temperature and moisture present in the grains. These are few of the major reasons responsible for fungicide and insects growth in the grains, which directly attack the kernel of the grains and fill the kernel with their eggs, pupa and larvae. The present paper shows the control of moisture and disinfestations of food grains with respect to selected power level and time. The paper presents the disinfestations of pulse beetle in selected pulses like whole mung bean, rajma and red lentil and kills the insect and their whole life cycle at the surface and kernel level. The domestic microwave is used to treat the pulses at different power levels 900 W, 720 W, 450 W, 270 W and 90 W for 30 Sec, 60 Sec and 90 Sec exposure times for disinfestations and to measure the moisture loss in pulses. And the acquired results of moisture further validated by the standard moisture meter DMM8. The moisture level of the whole mung bean varies from 7.80% to 7.22%, of rajma varies from 10% to 9.5% and of red lentil varies from 9.40% to 8.89%. And the protein contents of the pulses are calculated by the standard Kjheldal method, in which protein content of whole mung bean varies from 22.03% to 21.4%, of rajma varies from 22.5% to 22.3% and red lentil varies from 22.25% to 21.7%. All these samples are monitored for 90 days to analyse the mortality rate of the pulse beetle insects and their life cycle. Finally, it is observed that with controlled microwave energy the achieved mortality rate is approximately 95% in pulses

Keywords: Microwave heat treatment, disinfestations, Protein analysis, Moisture analysis

1. Introduction

According to the Govt. of India (GOI) report, in every year annual post-harvest loss (PHL) of major agriculture produce at the national level is about Rs. 96,651 core. Most of the post-harvest losses occur in the food grains, meat, poultry, fruits and vegetables and covers about 10-30% of the PHL. According to the study report cereals and Pulses are having 4.65 to 5.99% and 6.36 to 8.41% of the losses every year in India[1]. And Most of the food grains get spoiled due to the lack of storage conditions, unexpected environmental conditions. Due to an excess of moisture level in food grains, the insects and funguses attacks and destroy the grains. According to the literature review, food grains should maintain their moisture level in between 12 % to 16%[2]. So it is necessary to maintain the moisture level in food grains for increasing the quality of food grains. The dielectric properties of food grains also affect the quality factors of food grains. According to the literature life stages of T. Castaneum (eggs, larvae, pupae and adults) exposed to microwave radiation in wheat shows the mortality rate 100% at 400W [3].

Most of the research study reveals that 2.45GHz frequency based system is used to kill and remove the insects from the wheat and corn sample. The sampling time is very low 14 Sec, 28 Sec to 56 Sec with different power levels from 250W to 500W[4,5]. The literature shows that the mortality rate of the insect's increases and it maintains the moisture level of wheat and corn[4,5]. According to the author's studies, microwave heat treatment on several grains like wheat, ray and barley are reported the moisture control and disinfestations. It also decreases the germination rate of grains as the power level increases with respect to time [6,7].

Essential oil is the natural pesticide and used as botanical and microbial pesticides. It is one of the most popular traditional methods in rural India to preserve the stored food grains. Aegle Marmelos, Cymbopogon martini's essential oils used as semiochemicals mediating phytopesticide for the protection of stored wheat and gram from the beetles like C. Chinensis, R. Dominica and S. Oryzae and increases the stored food grains shelf life for 12 months to 24 months [8,9]. TNAU insect probe trap is a very handy instrument and easy to use. It is the probe-like shape and traps the larvae and adult pest such as R. Dominica, S. Cryzae (L.) and T. Castaneum (Herbst) from stored food grains like wheat and rice, etc. It uses 2-3 number/25kg bin (28cm diameter and 39cm length) for removal of greater than 80% of insects from the stored food grains [10]. The other type of plants Apiaceae, Lamiaceae, Lauraceae and Myrtaceae and their components with the mixture of CO2 or ethyl format protect the stored grains from the adults of beetle pests such as Tribolium Castaneum, Rhyzopertha Dominica, Sitophilus Oryzae and Sitophilus Zeamais [11].

Phosphine is used to control and delayed hatching of the Liposcelis bostrychophila, psocid and their pest eggs of the stored grain. Similarly, pirimiphos-methyl is used to treat the larvae of moth such as Indian meal moth, almond moth, rice moth, etc,. And the combination of vegetable oil and pirimiphos-methyl (10ml/kg: 1/4part) dosage at 20-300 C temperature is used to treat and preserve the wheat grain from the Sitophilus granaries (L.) [12]. Aluminium phosphide, bromodiolone, coumachlor, sodium cyanide and zinc phosphide are used as rodenticides and kill the rats and mice in the stored food grains. Now methyl bromide is banned due to its side effect on the environment such as it damage the Ozone depletion layer, it is highly toxic to humans and alleged carcinogen and the other side Phosphine is very toxic to mammals, alleged genotoxic [13,14]. 40MHz radio frequency is used to disinfestations of the pecan weevil, curculio caryae in pecans. At the lower frequency 39MHz, heating is used for the disinfestations of rice weevil in wheat. Similarly, 100% mortality of the codling moths achieved by the treatment of 27MHz radio frequency to the infested in-shell walnuts for 3 min [15].

This paper present microwave of 2.45GHz based treatment method for maintaining the protein level and moisture of the selected pulses.

2. Methodology

2.1 Microwave disinfestations principle

The heat treatment is based on the 2.45GHz frequency with the maximum 12.2cm penetration depth. In which electromagnetic heat energy is converted into the heat by the interaction between the polar molecules. When microwave heat falls on the pulses the water molecules present into the pulses samples tried to get align themselves with the field and creates friction in molecules. Because of that molecules generate heat and remove the moisture present into the pulses and at the same time kills the insects present into the pulses. The whole process takes place at the kernel level of the pulses and spread towards the surface [3]. Microwave heating is basically a volumetric heating, where the molecules present into the pulses directly absorb the microwave energy and convert into the internal heat, which is responsible for disinfestations of pulses and drying of pulses [3]. Equ. 1 shows the conversion method of converting the microwave energy into the heat [3,16,17].

$$P = 2\pi E^2 f \varepsilon_0 \varepsilon^{"} V \quad (1)$$

Where, P: power (W), E: electric field strength (V/m), f: microwave frequency (Hz), Ɛ0: permittivity of free space (F/m), Ɛ": dielectric loss factor and V: volume of the sample (m3)

Dielectric properties are the electrical characteristics and play the important role in the microwave heat treatment of pulses. These dielectric properties depend on upon the pulse's temperature, density and composition with the applied microwave frequency [18]. Rice weevil and confused flour beetle Insect's dielectric properties were first reported by the Nelson for the bulk samples at 40MHz frequency and show the effect of temperature and frequency on the insect's dielectric properties [19]. The dielectric properties of the food grains directly depend on upon the applied frequency and as the moisture contents in the food grains increase the dielectric constant increases [3]. the dielectric constant is the part of dielectric properties which is explained by the Equ. 2 [20]

$$\varepsilon^* = \varepsilon^{'} - j\varepsilon^{"} \quad (2)$$

Where, Ɛ*: complex relative permittivity, j=(-1)0.5, Ɛ': Dielectric constant (a real component, shows the material's store electromagnetic energy), Ɛ": dielectric loss factor (imaginary component, shows the material's dissipate electric energy into heat)

2.2 Moisture analysis

When the microwave energy is applied to the food grains the water molecules present into it get evaporated due to the conversion of microwave energy into the heat. The water molecules present into the food grains having a lower boiling point as compare to other nutritional parameters such as protein, carbohydrates, fats and amide, etc,. So due to the generated heat in food grains increases the loss of water molecules and responsible for the change in moisture level in food grains. The moisture level in food grains determines by the following expression (Equ. 3) [21,22].

$$\%\text{Moisture of food grain} = \frac{\text{Weight of the grain sample after drying}}{\text{Weight of the grain sample before drying}} \times 100 \quad (3)$$

So the loss of water molecules in the food grain samples determines the change in the moisture level in the food grain sample before and after heat treatment.

2.3 Insect and culture preparation

Pulse Beetle (Callosobruchus Chinensis) have been identified in the selected pulses such as whole mung bean, red lentil and rajma. The pulse beetle's eggs glued on the surface of the pulses and it is in the small oval shape with off white colour. The insect grows and lying hundreds of eggs at a time in 17 to 350C temperature with a various range of relative humidity and it's life cycle is 5 to 20 days[23]. The larvae and pupa directly feeding inside the food grains and causes the most damage.

Initially, three plastic jars filled with the whole mung bean, red lentil and rajma with weight 500gm/each. 50 insects placed inside the each jar and covered with the air holed plastic for proper aeration. The jars placed at 30±50C temperature with the relative humidity 50 to 75% for the controlled chamber for 6 weeks. After 6 weeks, insects grown up fully with their entire lifecycle (eggs, larvae and pupae). During the growing period, these insects damage the pulses around 75%.

2.4 Moisture measurement and Disinfestations method

Domestic microwave (Electrolux 26L Convection EJ26CSL4, 2.45GHz) used to treat the whole mung bean, red lentil and red kidney beans (rajma) and are stored in the desiccators. Different power levels such as 900 W, 720 W, 450 W, 270 W and 90 W used with 30 Sec, 60 Sec and 90 Sec exposure times to measure the moisture loss and disinfestations in selected pulses. Pulse beetle insect and their whole life cycle (eggs, larvae, pupae and adults) are targeted for the disinfestations in selected pulses. Fig. 1 shows the microwave energy based heat treatment for disinfestations and moisture analysis setup.

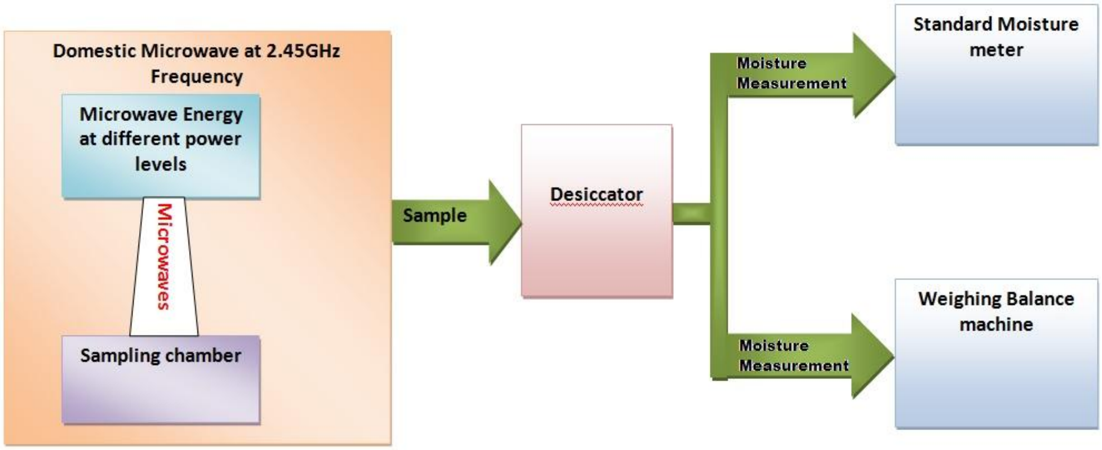

Fig. 1: Microwave heat treatment based disinfestations and Moisture analysis method

2.5 Mortality rate of pulse beetle

After the microwave heating for disinfestations of selected pulses, the mortality rate of the pulse beetle observed by the dead insects after the microwave heat exposure and total no. of insects present in the pulses before drying. Expression of the % insect mortality rate is shown in Equ. 4 [24].

$$\% \text{ Insect Mortality } = \frac{\text{No.of dead insects after microwave drying}}{\text{Total no.of insects before microwave drying}} \times 100 \quad (4)$$

2.6 Protein analysis

Protein is the main source of pulses but due to the attack of insects most of the pulses reduced their protein level and damaged fully. After treatment, protein level is the major nutritional factor to analyse and observed the effect of treatment. The protein contents of the treated pulses are analysed by using standard automated Kjeldahl method. The standard Kjeldahl method uses digestion, distillation and titration as the major processes to observed total nitrogen and protein in treated and untreated pulses (Fig. 2). The 0.2mg of powdered untreated and treated samples along with catalyst mixture (Potassium Sulphate & Cupric Sulphate) are used for the digestion process. The pulses samples initially preheated for 30 min at 3500C and then heated for 1 hour at 4200C. The digested samples turned into milky green, allowed to cool down for 15 min., and added 10ml of distilled water to dilute the sample to prevent it from crystallisation. And then diluted samples then gone through the distillation process and gives byproduct which further mixed with Indicator (Methyl Red & Bromocresol Green). These byproducts of the treated and untreated pulses samples used with the titration method to find out the total nitrogen in whole mung bean, rajma and red lentil samples by observing the titration value. The protein contents of the selected pulses further calculated through the standard nitrogen to protein conversion equation (Equ. 5 and Equ. 6).

$$\%\text{Moisture of food grain} = \frac{M_I - M_D}{M_I} \times 100 \tag{5}$$

$$\%\ \text{Proetin} = 6.24 \times \%\ \text{Nitrogen} \tag{6}$$

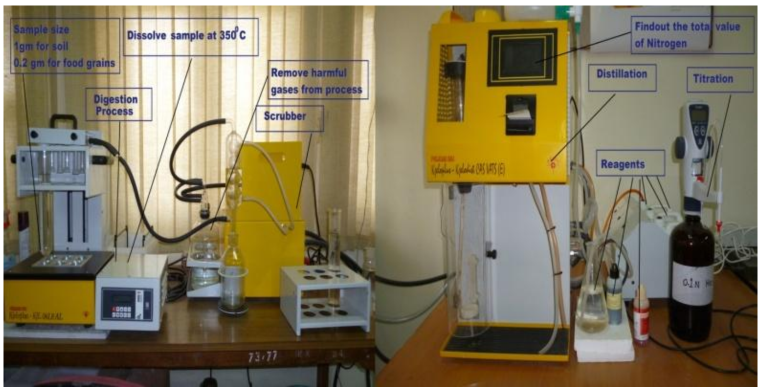

Fig. 2: Standard automated Kjeldahl method for Protein analysis

2.7 Statistical analysis

To measure the variability of the individual data and to estimate the sample mean dispersion are calculated by the statistical analysis such as Mean, Standard Deviation (SD), Variance and Standard Error (SE) of selected pulses were observed from the Matlab2015a software.

$$\text{Mean } (\bar{\chi}) = \frac{\sum_{i=1}^{n} \chi_i}{n} \tag{7}$$

$$\text{Standard Deviation (SD)} = \sqrt{\frac{\sum_{i=1}^{n} (\chi_i - \bar{\chi})^2}{n-1}} \tag{8}$$

$$\text{Standard Error (SE)} = \frac{SD}{\sqrt{n}} \tag{9}$$

$$\text{Variance } (\sigma^2) = \frac{\sum_{i=1}^{n} (\chi_i - \bar{\chi})^2}{n} \tag{10}$$

Whereχ_i: individual samples from i=1 to n and n: number of samples

3. Results and Discussion

Initial result shows that the selected pulses such as whole mung bean, red lentil and rajma are successfully disinfestated by the 2.45GHz microwave heat treatment. The domestic microwave oven also used for the moisture analysis of selected pulses at different power levels 900 W, 720

W, 450 W, 270 W and 90 W for 30 Sec, 60 Sec and 90 Sec exposure times. Which shows that 90W to 450W is the suitable range for disinfestations of the selected pulses without losing any protein contents. The most convenient range for the disinfestations of selected pulses was 270W to 450W with respect to the. sampling time 30sec to 60sec where all the insects and their whole life cycle (eggs, larvae, pupae and adults) killed and does not grow their generation even after 3 months of continuous monitoring. From the above experiment, the mortality rate of the pulse beetle are analysed for 3 months continuously and achieved approximately 95% in the treated pulses. From the Fig. 3, Fig. 4 and Fig. 5 clearly defined that microwave heat treatment does not affect the protein level of the treated pulses at 90W to 450W with time 30 sec to 90 sec. But after that very small variations occur at the protein level as the moisture level decreases in the treated pulses. Fig. 3 shows that the moisture level of the whole mung bean vary from 7.80% to 7.22% and protein contents vary from 22.03% to 21.4%, in Fig. 4 moisture level of red lentil varies from 9.40% to 8.89% and protein contents varies from 22.25% to 21.7% and in Fig. 5 moisture level of 10% to 9.5% and protein contents varies from 22.5% to 22.3%.

Table 1 and Table 2 shows the statistical behaviour of the protein and moisture of treated pulses. At 900W to 90W microwave power level, standard error of moisture in whole mung bean treatment varies from 0.0273% ± 0.0157%, for red lentil varies from 0.0321%± 0.0189% and for Rajma varies from 0.0306%± 0.108%. At the same time protein contents of the treated pulses varies with the correction factor 0.0636%± 0.067% in whole mung bean, 0.0173%± 0.060% in red lentil and 0.0153%± 0.018% in rajma beans.

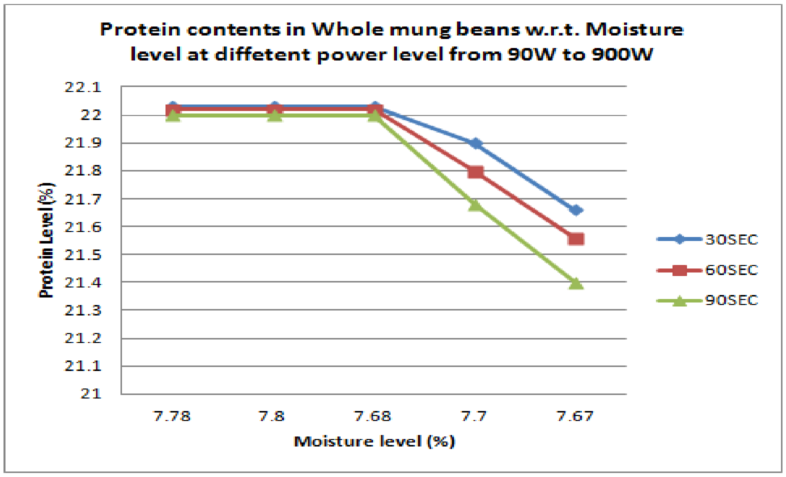

Fig. 3: Variation in total protein contents in treated Whole mung bean with moisture

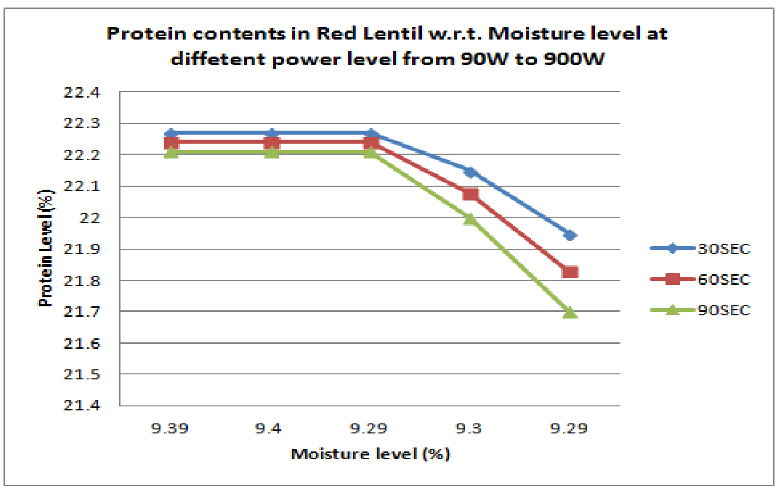

Fig. 4: Variation in total protein contents in Red lentil with moisture

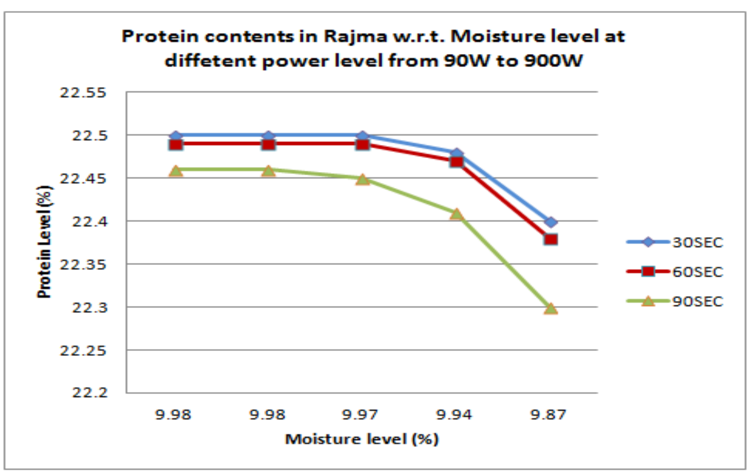

Fig. 5: Variation in total protein contents in Rajma with moisture

Table 1: Moisture content's statistical analysis of treated Whole Mung Bean, Red Lentil and Rajma at power level 900W to 90W along with time span 30sec to 90sec

S. No.	Power Level (W)	Mean	Maximum	Minimum	Variance	Standard Deviation	Standard Error
	Moisture content's statistical analysis in treated Whole Mung Bean						
1	900	7.633333	7.580000	7.670000	0.002233	0.047258	0.027285
2	750	7.666667	7.600000	7.700000	0.003333	0.057735	0.033333
3	450	7.633333	7.570000	7.680000	0.003233	0.056862	0.032830
4	270	7.766667	7.700000	7.800000	0.003333	0.057735	0.033333
5	90	7.753333	7.720000	7.780000	0.000933	0.030551	0.017638
	Moisture content's statistical analysis in treated Red Lentil						
6	900	9.240000	9.180000	9.290000	0.003100	0.055678	0.032146
7	750	9.266667	9.200000	9.300000	0.003333	0.057735	0.033333
8	450	9.243333	9.180000	9.290000	0.003233	0.056862	0.032830
9	270	9.366667	9.300000	9.400000	0.003333	0.057735	0.033333
10	90	9.366667	9.340000	9.390000	0.000633	0.025166	0.014530
	Moisture content's statistical analysis in treated Rajma						
11	900	9.710000	9.490000	9.870000	0.038800	0.196977	0.113725
12	750	9.906667	9.800000	9.980000	0.008933	0.094516	0.054569
13	450	9.926667	9.860000	9.970000	0.003433	0.058595	0.033830
14	270	9.920000	9.880000	9.980000	0.002800	0.052915	0.030551
15	90	9.970000	9.960000	9.980000	0.000100	0.010000	0.005774

Table 2: Protein content's statistical analysis of treated Whole Mung Bean, Red Lentil and Rajma at power level 900W to 90W along with time span 30sec to 90sec

S. No.	Power Level (W)	Mean	Maximum	Minimum	Variance	Standard Deviation	Standard Error
	Protein content's statistical analysis in treated Whole Mung Bean						
1	900	21.54000	21.40000	21.66000	0.017200	0.131149	0.075719
2	750	21.79333	21.68000	21.90000	0.012133	0.110151	0.063596
3	450	22.01667	22.00000	22.03000	0.000233	0.015275	0.008819
4	270	22.01667	22.00000	22.03000	0.000233	0.015275	0.008819
5	90	22.01667	22.00000	22.03000	0.000233	0.015275	0.008819
	Protein content's statistical analysis in treated Red Lentil						
6	900	21.82667	21.70000	21.95000	0.015633	0.125033	0.072188
7	750	22.07667	22.00000	22.15000	0.005633	0.075056	0.043333
8	450	22.24000	22.21000	22.27000	0.000900	0.030000	0.017321
9	270	22.24000	22.21000	22.27000	0.000900	0.030000	0.017321
10	90	22.48333	22.46000	22.50000	0.000433	0.020817	0.012019
	Protein content's statistical analysis in treated Rajma						
11	900	22.24000	22.21000	22.27000	0.000900	0.030000	0.017321
12	750	22.36000	22.30000	22.40000	0.002800	0.052915	0.030551
13	450	22.45333	22.41000	22.48000	0.001433	0.037859	0.021858
14	270	22.48000	22.45000	22.50000	0.000700	0.026458	0.015275
15	90	22.48333	22.46000	22.50000	0.000433	0.020817	0.012019

4. Conclusion

To maintain the grain quality it is necessary to check the nutritional status of grains time to time. The results show the control of moisture and disinfestations of food grains with respect to selected power level and time. Domestic microwave 2.45GHZ based microwave heat treatment is used for the disinfestations of pulse beetle in selected pulses like whole mung bean, rajma and red lentil and kills the insect and their whole life cycle at the surface and kernel level. All the selected pulses treated at different power levels 900 W, 720 W, 450 W, 270 W and 90 W for 30 Sec, 60 Sec and 90 Sec exposure times for disinfestations and for the measure the moisture loss. And the acquired results of moisture further validated by the standard moisture meter DMM8. The moisture level of the whole mung bean varies from 7.80% to 7.22%, of rajma varies from 10% to 9.5% and of red lentil varies from 9.40% to 8.89%. And the protein content of the whole mung bean varies from 22.03% to 21.4%, of rajma varies from 22.5% to 22.3% and red lentil varies from 22.25% to 21.7%. All these samples monitored for 90 days to analyse the mortality rate of the pulse beetle insects and their life cycle and the achieved mortality rate is approximately 95%. The further statistical analysis shows that at 270W to 450W is the convenient range for disinfestations of selected pulses with the time span 30 sec to 60 sec, where total protein contents of the pulses remain same. At 750W and above, the protein level of the treated pulses changes as the moisture level decreases with time. So microwave energy based heat treatment is one of the best futuristic technique for the disinfestations and drying of pulses and food grains without affecting the total protein contents of the food grains and it can prevent the spoilage of the food grains. So if we will be able to increase the scalability of the microwave technology then it could save at least 1% of the amount of the Post Harvest Losses. Then the futuristic microwave system will able to reduce the losses in a small time interval with very high efficiency.

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