Indian Journal of Ecology (2024) 51(4): 860-866
DOI: https://doi.org/10.55362/IJE/2024/4321

Manuscript Number: 4321
NAAS Rating: 5.38

Optimization of Process Parameters to Manage *Callosobruchus maculatus* (Fabricius) and Maintain Quality Parameters of Green Gram Grains (*Vigna radiata*)

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Abstract: The present study conducted to optimize the effect of different process parameters *i.e.* deltamethrin (0.025-0.075%), canola oil (0.50-1.50%), kinnow peel powder (0.50-1.50%) and storage period (2-6 month) to maintain physical and quality attributes by managing *Callosobruchus maculatus* in stored green gram grains (*Vigna radiata*). Under optimized conditions, the process parameters *i.e.* deltamethrin @ 0.027% for treating jute bags, canola oil @ 1.43% and kinnow peel powder @ 0.85% for treating green gram grains and stored for 6 month showed very less grain damage (0.17%) with minimum colour change (3.96) and optimum protein content (21.92%). The grains treated with optimized parameters required 62 min for their proper cooking and for overall acceptability, these grains scored 8 points (liked very much) based on hedonic sale. Above treated green gram samples with optimized parameters when compared with other tested treatments found to be in consonance with hermetic zerofly bag and metallic drum stored green gram grains with sand layer of 7 cm, revealing all the practices were at par for the effective control of pulse beetle without affecting the physical and quality attributes of green gram grains.

Keywords: Green gram, Pulse beetle, Canola oil, Kinnow peel powder, Insecticide, Storage, Grain quality

Post-harvest losses have become a growing concern globally for the grain supply chain. Among different post-harvest losses, insects are of great threat. Legumes, including green grams, are attacked by a beetle, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) in both the field and during storage (Srivastava and Subramanian 2016), causes significant losses when stored inappropriately (Jat et al 2013). The harm to the grain, which includes weight loss, a decline in commercial value, a reduction in nutritional content, and hygienic hazards, is caused by the insect's larval stage colonizing the interior section of the grain (Akami et al 2017, Saini et al 2022). Fungi and other secondary pests are more likely to appear because of the damage to the grains, which will reduce the quantity and quality of stored grains. Fumigation is the most practical and economical way to preserve grains particularly from insect-pests. However, due to their instability and detrimental impacts on commodities and humans, most gases have been eliminated. Methyl bromide is one of them, which has been taken out from the list of fumigants since it contributes to the ozone layer's depletion. Phosphine is a cheap insecticide that spreads swiftly through fumigant action and leaves little residue on the products, which makes it a popular choice for managing storage insects. Nevertheless, utilizing a single fumigant over an extended period runs the danger of making insect populations more resistant (Tay et al 2016). Moreover, at the discriminating phosphine concentrations, certain species have already shown 100% survival (Pimentel et al 2010).

Various non-chemical approaches are there to manage green gram at farm and under storage *viz.* cultural control, sealed containers, fine ash, inter-cropping, harvesting time, alternate host, heating and freezing effect, solar treatment and radiation treatments. Use of inert gases such as CO_2 and other method like ozonation (Kaur et al 2023) has also been used to control *C. maculatus* in stored green gram. But use of these gases also poses threat beyond a particular limit. To manage insect-pest, knowledge of the host range and biology of that insect are essential. Although insecticides are the most effective way for controlling insect-pests, but their long-term and careless use has been shown to be environmentally unsound. While, plant-derived compounds are easier to employ, more easily biodegradable, more targeted mode of action, less expensive, less dangerous and easily accessible. Keeping in view the hazardous effect of chemical fumigants, the present study was planned to find out the optimized doses of insecticide and botanicals to store green gram grains for longer period of time without altering their quality attributes.

MATERIAL AND METHODS

Procurement and preparation of sample: Green gram grains (SML 668) were procured from the local market and then disinfested at 60ºC temperature for one hour to make them free from any other insect infestation. Canola oil was procured from the Department of Processing and Food Engineering (DPFE), PAU, Ludhiana, while fresh kinnow peel was obtained from local vendors. The kinnow peel was cut into small pieces, dried in shade and pulverized into fine powders using an electric grinder.

Insect specie: *Callosobruchus maculatus* was collected from infested green gram grains from farmer's house and brought to Storage Laboratory of DPFE, PAU Ludhiana. The adult beetles of *C. maculatus* were then released on disinfested green gram grains in plastic jars covered with muslin cloth and tightened with rubber bands. These jars were kept in BOD incubators maintained at 29 ± 2ºC and 70 ± 5% relative humidity. Ten pairs of adult obtained from this culture were released in another jar with green gram grains. After 48 hours these adults were removed, and the grains were kept as such for about 25 days for the emergence of adults and were used for conducting the experiments.

Treatment details: Jute bags were treated with different doses of deltamethrin 2.8 EC (A) @ 0.025-0.075%, while green gram grains were treated with canola oil (B) @ 0.50-1.50% and kinnow peel powder (C) @ 0.50-1.50% with 2-6 month of storage period (D). Experiments were designed in factorial matrix (4-factors and 3-levels) with three center points of Box-Behnken of response surface methodology (RSM) using statistical software Design Expert 9.0 (StatEase) Box and Behnken (1960) having 27 runs. Based on different combinations obtained from the software, 5 kg green gram grains were packed in each bag with release of 10 pairs (10 males and 10 females) of freshly emerged adults of *C. maculatus* in each bag including untreated control and stored for 2, 4 and 6 months. The experiments were executed to investigate and optimize the process parameters *i.e.* deltamethrin, canola oil, kinnow peel powder and storage period to maintain physical and quality attributes of stored green gram grains by managing *C. maculatus*. Regression models for different responses were developed and optimized for the responses with significant model ($p < 0.05$) and non-significant lack of fit ($p > 0.05$) along with its desirability. The stored green gram grains under optimized process parameters were compared with hermetic zerofly bags, metallic drum with 7 cm sand layer (Anonymous 2023) and untreated control stored grains. All the treatments were analyzed for grain damage, grain weight loss, colour change, moisture content, protein content, cooking quality and overall acceptability of stored green gram grains.

Physical Attributes of Grains

Grain damage: The number of insect damaged grains was counted from 1000 grains of each treatment selected randomly at different storage intervals and per cent seed damage was calculated.

Grain weight loss: Treated and untreated grains were subjected for weight loss-based on number and weight of damaged and undamaged grains. After counting and weighing, grains were analyzed for per cent weight loss (Adams and Schulten 1978).

Colour change: Colour of the fresh and stored samples was measured in terms of 'L', 'a'and 'b' value by using Colour Reader CR-10 (Konica Minolta Sensing Inc.) and calculated (Gnanasekharan et al 1992).

Colour change = $[(L-Lo)2 + (a-ao)2 + (b-bo)2]^{1/2}$

Where, Lo, ao and bo represent the respective readings of fresh sample

Moisture content: Moisture content (%) of each sample was determined by oven drying at 105 ± 1°C for 24 h (Unal et al 2008).

Quality Attributes of Grains

Protein content: To calculate the protein content (%) in the samples, nitrogen content was estimated by using Micro-kjeldhal method (AOAC 2000). Nitrogen values were converted to protein by multiplying the factor of 6.25.

Cooking time: Optimum cooking time was determined by boiling 2 g green gram grains in 20 ml distilled water in hot water bath. During boiling, initially samples were removed after 30 min. and examined for its softness by pressing them between the forefingers and the thumb to determine the cooking time (Wani et al 2017).

Overall acceptability of grains: Overall acceptability was done by using organoleptic characters based on hedonic scale. The characters which was observed under organoleptic studies were colour, visual appearance, flavor, texture, overall acceptability including remarks by a panel of 5 semi-trained judges on 9 point hedonic scale with following individual scores: liked extremely-9, liked very much-8, liked moderately-7, liked slightly-6, neither liked or disliked-5, disliked slightly-4, disliked moderately-3, disliked very much-2 and disliked extremely-1 to find out the most acceptable treated green gram grains (Amerine et al 1965).

RESULTS AND DISCUSSION

Effect on grain damage and weight loss: The grain damage after giving different treatments varied from 0.0 to 3.6 % and significantly affected by canola oil concentration (B) and storage period (D). Grain damage was reduced by the application of oil on the surface of the grains since the coating of oil have ovicidal property, which causes poor oviposition, inhibits egg laying and F_1 progeny emergence (Wanderley et al 2020), thus reduced grain damage and weight loss. There were few treatment combinations, where no grain damage and weight loss were observed at 2 and 4 month of storage (Table 1). The maximum grain damage (3.6%) and weight loss (2.04%) were observed at 6 month of storage in the treatment combinations where deltamethrin (0.050%) was used to treat jute bags, while canola oil (0.50%) and kinnow peel powder (1.00%) were used to treat green gram grains. F-values and P-values of grain damage and weight loss were calculated. The canola oil percentage witnessed the significantly higher effect in comparison to other treatments recording F value 14.19 and 9.52 for grain damage and weight loss, respectively (Table 2). However, the present study showed no grain damage and weight loss with grains treated with 1.0 and 1.5% canola oil concentration along with other variables, below which witnessed more grain damage and weight loss. Further, egg mortality may be linked with toxic components of oil and to physical characteristics. The interaction term BD had significant effect on grain damage and weight loss. The regression equation showing canola oil (B) was having significantly negative and storage period (D) significantly positive effect on grain damage and weight loss (Table 3). The increase in canola oil percentage leads to decrease in grain damage and weight loss and if there is increase in storage period causes increase in per cent grain damage and weight loss. The results are consistent with those obtained by earlier researchers showing oil coating on grains reduced the attack of pulse beetle, *C. maculatus,* (Sharma et al 2019, Sharma et al 2022).

Effect on colour change of grains: The deltamethrin and canola oil treatment as well as deltamethrin and storage period on colour change of green gram grains under varying

Table 1. Experimental data on quality of green gram grains for response surface analysis

Experimenta combinations	Process variables				Product quality responses						
	Deltamethrin 2.8 EC (%)	Canola oil (%)	Kinnow peel powder (%)	Storage methods (Months)	Grain damage (%)	Weight loss (%)	Colour Change	Moisture content (%)	Protein content (%)	Cooking time (min)	Overall acceptability
1.	0.025 (-1)	0.50 (-1)	1.00 (0)	4 (0)	1.2	0.63	4.82	10.2	24.04	69	3
2.	0.075 (+1)	0.50(-1)	1.00(0)	4 (0)	2.9	1.64	6.09	9.4	24.04	68	3
3.	0.025 (-1)	1.50 (+1)	1.00 (0)	4 (0)	0.2	0.06	3.91	10.2	22.25	62	6
4.	0.075 (+1)	1.50 (+1)	1.00(0)	4 (0)	0.2	0.06	4.51	10.4	26.94	62	5
5.	0.050 (0)	1.00 (0)	0.50 (-1)	2 (-1)	0.1	0.05	2.25	10.5	25.98	67	8
6.	0.050 (0)	1.00 (0)	1.50 (+1)	2 (-1)	0.0	0.00	2.34	10.3	26.03	66	8
7.	0.050 (0)	1.00 (0)	0.50 (-1)	6(+1)	0.2	0.17	3.22	10.4	22.10	67	8
8.	0.050 (0)	1.00 (0)	1.50 (+1)	6(+1)	1.2	0.66	4.21	10.4	23.64	66	5
9.	0.025 (-1)	1.00 (0)	1.00 (0)	2 (-1)	0.0	0.00	2.89	10.3	26.00	67	8
10.	0.075 (+1)	1.00 (0)	1.00 (0)	2 (-1)	0.0	0.00	3.26	10.1	25.83	65	8
11.	0.025 (-1)	1.00 (0)	1.00 (0)	6(+1)	0.3	0.08	3.66	10.8	24.92	66	8
12.	0.075 (+1)	1.00 (0)	1.00 (0)	6(+1)	0.3	0.11	3.09	10.8	21.08	65	4
13.	0.050 (0)	0.50 (-1)	0.50 (-1)	4 (0)	0.6	0.30	4.44	10.3	24.02	68	3
14.	0.050 (0)	1.50 (+1)	0.50 (-1)	4 (0)	0.0	0.00	5.80	10.2	21.89	62	5
15.	0.050 (0)	0.50 (-1)	1.50 (+1)	4 (0)	0.5	0.22	5.85	10.2	21.67	69	5
16.	0.050 (0)	1.50 (+1)	1.50 (+1)	4 (0)	0.2	0.15	4.92	10.1	23.95	63	5
17.	0.025 (-1)	1.00 (0)	0.50 (-1)	4 (0)	0.3	0.11	4.22	10.4	22.73	67	7
18.	0.075 (+1)	1.00 (0)	0.50 (-1)	4 (0)	0.0	0.00	4.99	10.2	21.08	67	8
19.	0.025 (-1)	1.00 (0)	1.50 (+1)	4 (0)	0.6	0.30	5.03	10.2	25.96	68	6
20.	0.075 (+1)	1.00 (0)	1.50 (+1)	4 (0)	0.3	0.16	6.05	10.0	21.51	68	5
21.	0.050 (0)	0.50 (-1)	1.00 (0)	2 (-1)	0.2	0.09	3.19	10.4	23.73	68	7
22.	0.050 (0)	1.50 (+1)	1.00 (0)	2 (-1)	0.0	0.00	4.01	10.3	26.06	64	7
23.	0.050 (0)	0.50(-1)	1.00 (0)	6(+1)	3.6	2.04	3.16	10.1	23.98	68	2
24.	0.050 (0)	1.50 (+1)	1.00 (0)	6(+1)	0.3	0.14	4.34	10.4	23.51	62	5
25.	0.050 (0)	1.00(0)	1.00 (0)	4 (0)	0.2	0.07	4.40	10.3	26.58	66	5
26.	0.050 (0)	1.00 (0)	1.00(0)	4 (0)	0.1	0.07	4.64	10.4	26.65	67	6
27.	0.050 (0)	1.00 (0)	1.00 (0)	4 (0)	0.2	0.05	4.50	10.3	24.24	66	5

process conditions ranged from 2.25 to 6.09 irrespective of the experimental combinations (Table 1). There was non-significant effect of all combinations of independent variables on colour change. The quadratic terms of D^2 was significant on colour change of green gram grains recording F value 26.92 (Tables 2, 3). Similar results were obtained on maize grains by Ogendo et al (2004) where grain colour and odour were unaffected by the botanicals.

Effect on moisture content of grains (%): The variation in moisture content was due to different combinations of independent variables and ranged from 9.4 to 10.8 % (Table 1). There was non-significant effect of all independent variables *i.e.* deltamethrin, canola oil, kinnow peel powder and storage period on moisture content. However, the interaction of AB had significant effect on moisture content (Tables 2, 3). Kadam et al (2013) also observed that moisture content in the seed stored for three years of study was non-significant and remained within the safe limit throughout the storage period. In present study, the moisture content of grains were found to be in safe limit which may be due to surface application of canola oil and kinnow peel powder on grains which cover the pores in the grain coat and prevents the entry of water and fungal mycelia and provide protection from physical damage as observed by Beedi et al (2018) in gram and Rathinavel and Raja (2007) in cotton seed.

Effect on protein content of grains (%): Various treatment combinations showed protein variability in green gram grains ranged from 21.08 to 26.65% during 6 month of storage. The storage period had negative but significant effect, while other independent variables had non-significant effect on per cent protein content. The interaction and quadratic effects of deltamethrin, canola oil and storage period for green gram used in various combinations were found to be non-significant. But the quadratic terms of C^2 was significant on protein per cent of green gram grains (Tables 2, 3).

Effect on cooking time of grains (min): The cooking time after giving different treatments varied from 62 to 69 min. The canola oil (B) had negative but significant effect on cooking time (Table 2). This witnessing that the increased canola oil percentage reduced the time required to cook the grains, which may be due to the softness of seed coat without altering the cooking quality and supported by Wanderley et al (2020). All other parameters had non-significant effect on cooking time (Table 3).

Effect on overall acceptability (OA) of grains: The overall acceptability of green gram grains was adjudged based on 9-point hedonic scale and varied from 2.0 to 8.0 points (Table 1). Canola oil and storage period had significant effect on overall acceptability of green gram grains. The results also witnessing that increase in canola oil percentage leads to

Table 2. ANOVA of process parameters for physical and quality attributes of grains

Parameters	F-value						
	Grain damage (%)	Grain Weight loss (%)	Colour Change	Moisture content (%)	Protein content (%)	Cooking time (min.)	Overall acceptability
Model	2.65**	1.15 ^{ns}	3.83*	1.64 ^{ns}	1.85 ^{ns}	10.70**	5.54**
A	0.26 ^{ns}	0.62 ^{ns}	2.24 ^{ns}	2.50 ^{ns}	1.05 ^{ns}	1.70 ^{ns}	2.19 ^{ns}
B	14.19*	9.52*	8.75 x 10^{-4} ^{ns}	1.73 ^{ns}	0.35 ^{ns}	130.09*	8.76**
C	0.55 ^{ns}	3.68 x 10^{-3} ^{ns}	2.23 ^{ns}	1.11 ^{ns}	0.88 ^{ns}	0.42 ^{ns}	2.19 ^{ns}
D	6.78**	2.01 ^{ns}	2.58 ^{ns}	1.73 ^{ns}	7.43**	0.96 ^{ns}	17.17*
AB	1.87 ^{ns}	1.94 ^{ns}	0.26 ^{ns}	5.20**	2.36 ^{ns}	0.32 ^{ns}	0.26 ^{ns}
AC	0.000 ^{ns}	1.32 x 10^{-5} ^{ns}	0.035 ^{ns}	0.000 ^{ns}	0.84 ^{ns}	0.00 ^{ns}	1.05 ^{ns}
AD	0.000 ^{ns}	1.32 x 10^{-5} ^{ns}	0.48 ^{ns}	0.21 ^{ns}	1.45 ^{ns}	0.32 ^{ns}	4.20 ^{ns}
BC	0.058 ^{ns}	7.57 x 10^{-4} ^{ns}	2.92 ^{ns}	0.000 ^{ns}	2.09 ^{ns}	0.00 ^{ns}	1.05 ^{ns}
BD	6.23**	5.29**	0.070 ^{ns}	0.83 ^{ns}	0.84 ^{ns}	1.27 ^{ns}	2.36 ^{ns}
CD	0.79 ^{ns}	4.19 x 10^{-3} ^{ns}	0.44 ^{ns}	0.21 ^{ns}	0.24 ^{ns}	0.00 ^{ns}	2.36 ^{ns}
A^2	0.15 ^{ns}	0.45 ^{ns}	0.12 ^{ns}	0.49 ^{ns}	2.23 ^{ns}	0.047 ^{ns}	0.97 ^{ns}
B^2	4.25 ^{ns}	4.10 ^{ns}	2.01 ^{ns}	3.08 ^{ns}	2.40 ^{ns}	7.37 ^{ns}	11.92*
C^2	0.47 ^{ns}	0.94 ^{ns}	0.46 ^{ns}	0.19 ^{ns}	6.73**	2.31 ^{ns}	2.49 ^{ns}
D^2	0.12 ^{ns}	0.10 ^{ns}	26.92*	2.78 ^{ns}	0.072 ^{ns}	0.58 ^{ns}	9.35*
Lack of fit	10.47 ^{ns}	1.44 ^{ns}	10.03 ^{ns}	17.10 ^{ns}	1.26 ^{ns}	2.62 ^{ns}	3.22 ^{ns}

*Indicates p value as significant at 1% level of significance, ** at 5 % level of significance
Where, A- Deltamethrin 2.8EC, B-Canola oil, C-Kinnow peel powder, D-Storage period

increase in overall acceptability of green gram grains which may be due to shinning look of the grains by application of canola oil on the surface of grains. Canola oil had positive, while storage period had negative effect on the overall acceptability of green gram grains. Thus, increases in storage period reduce the overall acceptability of green gram grains. The quadratic terms of B^2 and D^2 had significant effect on overall acceptability of green gram grains (Tables 2, 3).

Optimization of process parameters: The results of the analysis discussed above have been used to optimize various process parameters *i.e.* deltamethrin (A), canola oil (B), kinnow peel powder (C) and storage period (D) to protect green gram grains from *C. maculatus*. In optimizing process parameters, the results were aimed to have minimum grain damage, colour change and cooking time as well as maximum overall acceptability. The optimized conditions *viz.* deltamethrin 2.8 EC @ 0.027%, canola oil @ 1.43%, kinnow peel powder @ 0.85% with 6 month of storage period resulted in minimum grain damage (0.17 %), minimum colour change (3.96), optimum protein content (21.92%), minimum cooking time (62 min) with maximum overall acceptability (8 point) showing a desirability of 0.851 (Table 4).

End-use quality comparison of optimized parameters with hermetic zerofly, metallic drum with sand layer and untreated control stored green gram grains: The various physical and quality attributes of green gram grains stored with optimized parameters were compared with hermetic zerofly, metallic drum with sand layer and untreated control (Table 5). The results revealed that the grain damage to green gram in optimized parameters, hermetic zerofly bag, metallic drum and untreated control stored grains were 0.17, 1.8, 0.0 and 71.6%, respectively at 6 month of storage period. The less grain damage in optimized parameters showed the effect of insecticide and botanicals, while in hermetic zerofly bag, it was probably due to oxygen starvation which plays a role in killing or less multiplication of insects as compared to untreated control (Yewle et al 2022). There was no grain damage to metallic drum with 7cm layer of sand stored grains

Table 3. Regression models developed for prediction of responses

Regression equation	Best model	R^2
Grain damage=0.27+0.092*A-0.68*B+0.13*C+0.47*D-0.42*AB+0.00*AC+0.00*AD +0.075*BC0.77*BD+0.27*CD+0.10*A^2+0.55*B^2-0.18*C^2+0.092*D^2	Quadratic	0.75
Weight loss=0.11+0.94*A-3.67*B+0.072*C+1.69*D-2.87*AB-7.5x10^{-3}*AC +7.5 x10^{-3}*AD + 0.057*BC-4.74*BD +0.13*CD +1.20*A^2 +3.62*B^2-1.73*C^2+0.57*D^2	Quadratic	0.69
Colour change=4.58+0.29*A-5.5 x10^{-3}*B +0.29*C+0.31*D-0.17*AB+0.0063*AC-0.23*AD-0.58*BC+0.089*BD +0.22*CD +0.100*A^2 +0.41*B^2+0.20*C^2-1.51*D^2	Quadratic	0.82
Moisture content=10.33-0.10*A+0.083*B +0.067*C+0.083*D+0.25*AB+0.000*AC +0.050*AD-0.000*BC+0.10*BD +0.050*CD-0.067*A^2 0.17*B^2+0.042*C^2+1.16*D^2	Quadratic	0.66
Protein content=25.82-0.45*A+0.26*B +0.41*C-1.20*D+1.17*AB-0.70*AC -0.92*AD+1.10*BC-0.70*BD +0.37*CD-0.99*A^2 -1.02*B^2+1.71*C^2-0.18*D^2	Quadratic	0.68
Cooking time=66.33-0.33*A-2.92*B+0.17*C-0.25*D+0.25*AB+0.00*AC +0.25*AD+0.00*BC-0.50*BD +0.00*CD+0.083*A^2 -1.04*B^2+0.58*C^2-0.29*D^2	Quadratic	0.92
Overall acceptability=5.33-0.42*A+0.83*B-0.42*C-1.17*D-0.25*AB-0.50*AC -1.00*AD-0.50*BC+0.75*BD +0.75*CD+0.42*A^2 -1.46*B^2+0.67*C^2-1.29*D^2	Quadratic	0.87

Table 4. Optimum values of process parameters and responses for green gram grains

Process parameters	Target	Experimental range		Optimum values	Desirability
		Minimum	Maximum		
Deltamethrin (%)	Range	0.025	0.075	0.027	0.851
Canola oil (%)	Range	0.50	1.50	1.43	
Kinnow peel powder (%)	Range	0.50	1.50	0.85	
Storage period	Range	2.00	6.00	6.00	
Responses					
Grain damage (%)	Minimize	0.00	3.6	0.176	
Colour change	Minimize	2.246	6.095	3.96	
Cooking time (min)	Minimize	62.00	69.00	62.00	
Overall acceptability	Maximize	2.00	8.00	8.00	
Protein content (%)	Range	21.08	26.94	21.92	

which may be due to restriction in movement of beetles as inter-granular space was filled with sand, which leads to death of beetles even before mating. All the tested treatments were superior to untreated control to store green gram grains for a period of 6 month. The colour change of green gram grains under various treatments showed maximum change in untreated control (4.21) at 6 month of storage, which may be due to presence of eggs on grains or insect eaten grains, which leads to degradation of colour during storage (Kaur et al 2013). Minimum colour change of green gram grains were under optimized parameters and hermetic zerofly bags at 6 month of storage and supported by Yeole et al (2018) where green gram can be stored up to 6 month in hermetic bag without any fumigation maintained the food quality. Further, no change in colour was observed in metallic bin stored green gram grains (2.18) when compared with initial colour (2.17) of grains as observed by Saini et al (2022). The moisture content in green gram grains stored with optimized doses were 10.20%, while in hermetic zerofly bags, metallic bin and untreated control stored grains were 8.50, 9.80 and 10.50%, respectively at 6 month of storage Kadam et al (2013) also recorded the moisture content ranged from 8.34 to 8.66 per cent after 9 month of storage of chickpea and 10.1 to 10.8 % recorded in stored green gram seed for 6 month (Saini et al 2022). The protein is an important nutritional parameter for human being, 26.27% protein content was recorded initially in green gram grains used for storage. The protein content 21.92, 25.10, 26.26 and 25.51% were recorded under optimized parameters, hermetic zerofly bag, metallic bin and untreated control stored grains, respectively. The protein content in untreated control grains didn't fall much, which may be due to the presence of insects, eggs and their excreta on/in grains which contributed a major part of N_2 estimated in the damaged grains and then converted into crude proteins. Similar trend was observed by Hamdi et al (2017) and Mbah and Silas (2007) that protein content increased in infested cowpea seeds. There was very little difference in cooking time observed in various treatments *i.e.* 62 min required to cook green gram grains stored under optimized parameters, while 65 and 63 min required for hermetic zerofly and metallic bin stored green gram grains, respectively. Minimum time was recorded to cook untreated green gram grains (57 min), which may be due the presence of insect eaten grains. In overall acceptability of green gram grains, 8 point (liked very much) was scored by grains stored with optimized parameters and hermetic zerofly bag for 6 month, which may be due to coating of oil give shining appearance to grains and less insect incidence. Further, metallic drum stored green gram grains scored 9 point (liked extremely), which may be because the drum retain the actual appearance of grains even at 6 month of storage. Least score *i.e.* 2 (disliked very much) were recorded for green gram grains stored in untreated control bags, which may be due to heavy infestation, egg laid on grains and presence of insect

Table 5. End-use quality comparison of optimized parameters with hermetic zerofly, metallic drum with sand layer and untreated control stored green gram grains

Process parameters	Responses					
	Grain damage (%)	Colour Change	Moisture content (%)	Protein content (%)	Cooking time (min.)	Overall acceptability (score)
Optimized values of D:CO:KPP:SP (0.027:1.43:0.85:6.00)	0.17	3.96	10.20	21.92	62	8.0
Hermetic zerofly bag						
2 month	0.4	3.36	11.10	24.70	65	8.0
4 month	1.4	3.60	10.60	25.30	63	8.0
6 month	1.8	3.71	8.50	25.10	65	8.0
Metallic drum with sand layer						
2 month	0.0	2.17	10.40	26.21	66	9.0
4 month	0.0	2.17	10.20	26.25	65	9.0
6 month	0.0	2.18	9.80	26.26	63	9.0
Untreated control						
2 month	5.40	3.73	10.00	24.17	60	5.0
4 month	59.6	4.16	10.10	25.23	58	2.0
6 month	71.6	4.21	10.50	25.51	57	1.0

D= Deltamethrin, CO= Canola Oil, KPP= Kinnow Peel Powder, SP= Storage period
Fresh sample: Protein content- 26.27 %, Moisture content- 10.20%, Colour change- 2.17

eaten grains which gave bad appearance and renders them unfit for consumption.

CONCLUSIONS

Green gram was successfully stored for a period of six month with the use of optimized parameters of deltamethrin, canola oil and kinnow peel powder. The above-treated green gram samples under optimal conditions agreed with the hermetic zerofly and metallic drum containing the sand layer storing the green gram grains, indicating that all the practices were at par for the efficient control of pulse beetle without degrading the quality criteria. This indicate that treatment of green gram with optimized conditions can be used as a part of integrated pest management for safe storage of green gram grains.

ACKNOWLEDGEMENTS

The authors thank the ICAR- AICRP on Post-harvest Engineering and Technology, New Delhi for financial support.

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Received 29 March, 2024; Accepted 30 June, 2024