USING THERMAL TREATMENT TO ELIMINATE COWPEA BEETLE *CALLOSOBRUCHUS MACULATUS (F.)* INFESTING FABA BEAN DURING STORAGE AND ITS EFFECT ON THE PHYSIOCHEMICAL AND TECHNOLOGICAL PROPERTIES

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Abstract

Thermal disinfestations consider one of the methods of physical insect control. Eggs, larvae, pupae, and adults of *callosobruchus maculates* were introduced at 50,60,70 and-5, -10ºC for varying durations 5,10,15,30,45,60,75 and 90 min. Results indicated that, adults survival decreased with exposure times increase, complete mortality was achieved at 50,60 and 70ºC for 50,40 and 30 min. of exposure times respectively. On the other hand, highly sensitive due to low temperature was recorded at -10ºC followed by -5ºC within 25 and 30 min. respectively, which resulted in complete mortality. So, the degree of -10ºC resulted in preventing any hatch and development of eggs, any emergence for all immature stages after 45 min. then, the reduction of progeny was 100%. Due to the above mentioned results, treatments of 60ºC and -10ºC for 75 and 45 min. respectively, were selected to evaluate the physiochemical and technological properties. Results indicated that the color of control and treated faba bean at low and high temperature indicated that both high and control samples "L" value significantly decreased ($p > 0.05$), "a" value increased after treated with high temperature while, "b" value increased in low temperature treated seeds. Protein content showed no significant differences of both low and high temperature and control. Cookability of seeds and protein digestibility were higher in high temperature samples than low temperature treated seeds and control. On other hand, bioactive compounds (phytic acid, tannins and total phenols) reduced in high temperature compared with low temperature treated seeds and control sample. Sensory evaluation of cooked faba bean showed non significant differences in all sensory parameters compared with control. Finally, it could be said that the thermal treatments of legumes is one of the best physical methods used to kill the insects of legumes and their stages and thus keep the seeds also maintaining its physicochemical properties and did not cause loss of protein.

INTRODUCTION

Physical methods have been used to control stored grains insects for thousands of years. The golden rule in the Nile delta of proper seed storage such as keep grain cool and dry was used in neo lithic times by placing clay jars underground. Nowadays, from medicates environmental factors physical control of stored seeds insects (i.e. moisture content, temperature and relative humidity) in compositions containing

wares (silos, elevators, bags, packaging). For several years the use of physical control means like the use of terminus temperatures, specially low temperatures, has been widely used to control stored grains insects. The virtues of means are that: (1) after treatment there are no remnants in grains. (2) They are resistant against pesticide strains, and (3) there are little risks (Paul,2012). Increase of temperature from 35 ºC to 60 ºC affect the ionic activity of molecules doubles the solubility of oxygen in water, increases the hydrogen ion by 2.5 times and has no effect on the solubility of Nacl. According to radically change the rendition of enzymes regard to small changes in pH. For most species of stored crops insect vermin, freezing is lethal. The stellar cooling point ranges between -10 and -25 ºC and is consequent upon many factors such as species, stage,and feeding state. (Mekasha *et al.* 2006).

The stellar cooling point therefore idealizes the lower fatal temperature for stored-crops insects. Because ice crystals destroy the cells and cause death due to osmotic imbalances when salts are concentrated as the water is bound in ice also, Ice preempts the motion of molecules within and between the cells (johnson ad Valero, 2000).

In stellar cooling degrees under these conditions there is exciting increase in the ability of the insects to tolerate in low points when insects are exposured to temperature between 5 and 15 ºC.

Faba beans is stable crop with historical importance as a food crop for people and animals in most part of the world such as Africa and Asia with other legumes. The scientific name of Faba beans is (*Vicia faba L.*) and it is known as tick beans, field beans and broad bean. Faba beans (*Vicia faba L.*) are an excellent protein source and should be more present in human diet. (Liene and Sandra, 2016). It contains an amount of carbohydrate (50-65%), dietary fibers (10-12%) and dry matter varied from 85.6% to 92.5%. Faba bean (*Vicia faba L.*) seeds are rich in dietary minerals, B-group vitamins and phenolic compounds (Baginsky *et al.,* 2013). The proteins of legumes retrofitted preventative effects for many chronic diseases like cancer, obesity diabetes and cardiovascular diseases. Dried faba bean contained moderately amino acids and 20–28% protein with well-balanced high lysine content (Ye *et al.* 2000). The legumes require sufficient processing before consumption. Dry faba beans need soaked to become soft or ground to a paste with other ingredients then fried to eat. However, soaking followed by cooking is the most common way of the production of edible legume products. Cooking of soaked faba bean seeds develop aroma and improve the overall acceptability of the legumes. It also increases the bioavailability of the nutrients as improving the in vitro protein digestibility by reduction the antinutritional factor.(Guzel and Sayar 2012).

The objectives of the present investigation were to study the optimum temperature (heat or cold) and time of exposure on the mortality of the different stages of *callosobruchus maculatus (F.)* followed by the physicochemical and technological properties of the treated faba bean seeds.

MATERIALS AND METHODS

Insect cultures:

Cultures of the cowpea beetle; *callosobruchus maculatus (F.)* were reared on faba bean (variety Giza 2) at 27ºC and 65ºC ± 5% r.h. Before each trail, faba bean was fumigated by phostoxin tablets for at least three days to exclude infestation by insects.

A- Biological and toxicological studies:

Preparation the stages:-

Egg stage:

For this study, twenty pairs of the freshly emerged adults of *C.maculatus* 1-2 days-old) were permitted to lay eggs into plastic jars with perforated lids containing 20 gm seeds .The adults were removed after 24 h., and then seeds bearing eggs were count and kept in the rearing room for 24 – 48 h.

Immature stage:

For the immature stages (larvae and pupae) in the experiment, 20 pairs of adults *C.maculatus (F.)* were kept for two days on 50 gm. seeds in rearing jars with perforated lids. After that, the adults were removed and then seeds infested with eggs kept in rearing room for two weeks (to obtain larval stage), another group were kept for three weeks (to obtain papal stage).

Adult's stage:

In this study, 20 pairs of adults *C. maculatus* newly emerged from the same cultures were placed in glass tubes with perforated lids to start the experiment.

Experimental set-up:

The previous groups bearing eggs, larvae, pupae and adults were exposed to 50,60,70,-5 and -10ºC for 5,10,15,20,25,30,35,40,45,50,60,70,75 and 90 minutes, while, untreated control of every stage was kept in the rearing room at 27ºC and 65± 5% r.h. After the exposure to treated temperature and exposure times, the groups transferred to insect rearing room at the same previous condition. All experiments were carried out in three replicates.

Survival of different development stages to high and low temperature:

Total number of eggs, hatching eggs and adult emergence were recorded. Results were given according to the percentage reduction of adult emergence from eggs and other immature stages compared with the reduction of control.

Adult mortality:

The number of dead and live insects was counted. Mortality was determined by complete lack of movement after treatment. Although individuals were often obviously affected, such as sluggish behavior and uncoordinated movement, it was considered alive due to lack of information as to potential recovery.

Technological studied were done only on by to temperature and time of exposed were achieved reduction that gave 100%of tested insect for all stages, (60ºC for 75 min. and -10ºC for 45 min.)

As mentioned above, treatments of 60ºC and -10ºC for 75 min. and 45 min. respectively were selected to evaluate the physicochemical and technological properties of treated faba bean seeds.

B- Physicochemical and technological properties.

Ingredients and chemicals.

The faba bean seeds (Giza 2) were obtained from Field Crops Research Institute, Agriculture Research Center, Ministry of Agriculture, Giza, Egypt. And treated in Insects Research Institute, Dokki, Giza., pepsin and pancreatin were purchased from Sigma-Aldrich Chemical Co., St. Louis, USA. All other used chemicals were analytical grade.

Physical properties.

Treated seeds were exposed (-10 ºC for 45 min and 60 ºC for 75 min) and control (untreated) seeds at room temperature for determination of physical properties as follows:

100 seed weight, seed size and weight, seed density and seed dimensions were determined according to the method described by Shehata (1982). Seeds surface Colour was measured using Hunter Lab colorimeter (Color Quest XE, Hunter Association Lab. Inc., Reston V.A. USA) (Hunter Lab, CQ X3397) according to Guzel and Sayar (2012).

Analytic Methods.

Faba bean seeds were milled into fine powder. The bean fine powder was subjected to moisture, protein, fiber, ash and fat determination**.** Where carbohydrate value was calculated by difference according to (A.O.A.C. 2016).

Determination of Minerals:

Minerals content was estimated by Atomic Absorption Spectrophotometer (model 3300, perkin - Elimer, Bea consfield, U.K) according to the procedure outlined by (A.O.A.C. 2016).

Determination of bioactive components:

Phytic acid, Tannins and Total phenols of faba bean seed were determined as described by Price and Butler (1977).

In Vitro Protein Digestibility:

Protein digestibility of faba bean samples was determined according to the method of Saunders *et al.* (1973). After enzymatic digestion of samples with pepsin and pancreatin, the protein in the resultant supernatant was estimated using the Kjeldahl method. The percentage of protein digestibility was calculated by the ratio of protein in the supernatant to protein in the sample as the following equation:

Protein digestibility (%) $= \frac{N \text{ in supernatant} - N \text{ in Blank}}{N \text{ in sample}} \times 100$

N= Nitrogen

Technological process.

Soaking treatment. Samples were soaked in tap water over-night (12 hrs.) and the hydration coefficient % was determined.

Hydration coefficient% $= \frac{\text{Wt. of soaked seeds} - \text{Intial wt. of seeds}}{\text{Intial wt. of seeds}} \times 100$

After soaking time (12 hrs.), seeds were dehulled then, the seed coat or (hulls) and the cotyledons dried in Lab. oven (60 ^{o}C/12hrs.) and weighted to calculate % of the seed coat and the cotyledons according to Fahmy *et al.* (1996).

Cooking process

Faba been seeds were cooked according to the method described by Fahmy *et al.* (1996). The imbibed water % was determined in cooked seeds using the following equation:

Imbibed water % $= \frac{\text{Wt. of cooked seeds} - \text{Intial wt. of seeds}}{\text{Intial wt. of seeds}} \times 100$

Water soluble materials or total soluble solids (TSS):

The cooking water contained soluble materials was poured into porcelain pot and placed in an oven at 60 ^{o}C until all the cooking water was evaporated. The pot was weighted and TSS calculate daccording to Fahmy *et al.* (1996) as follows:

TSS % $= \frac{\text{Wt. of pot after drying} - \text{Weight of empty pot}}{\text{Intial wt. of seeds}} \times 100$

Cookability: The ability of cooked seeds was measured by means of using the normal press of fingers and comparing between the cooked seeds for their hardness.

Sensory evaluation.

Three cooked faba bean samples were sensory evaluated after stewing according to Fahmy *et al.* (1996) by ten well trained panelists from the staff members of Food Technology Research Institute at ARC, Ministry of Agriculture, Giza, Egypt. The scoring scheme was established for color, taste, odor, appearance and overall acceptability.

Statistical analysis. Were carried out by spss vr. 20 programs. Data were expressed as mean ± S.D. and the statistical analysis were performed one-way analysis of variance followed by Duncan's tests. (IBM Corp. Released 2011).

RESULTS AND DISCUSSIN

Exposure *of C.maculatus* adults to 50,60 and 70ºC at different exposure times was studied . Table (1) proved that, high temperature level and increases exposure times were resulted in increasing in average mortality. Adult survival decreased with increase of exposure times (Abdullah *et al*. 2016) Complete mortality of *C. maculatus* was achieved in 50, 60 and 70 ºC at 50,40,30 min. of exposure times respeetively. From the other hand, the exposure to low temperatures (-5 ºC and -10 ºC) revealed that ,the pest was highly sensitive to low temperature (-10ºC) which led to complete mortality after 25 min. and within 30 min at -5ºC compared with untreated control which showed mortality percentage of 2.3% (at room temperature) .

In conclusion, *C.maculatus* was most sensitive to the low temperature during seeds cooling ,this may be due to the thermophility of the pest . So, the effect of high temperature was lower than cooling treatment on the tested pest specially at 50 and 60 ºC. These results agreed with Salha *et al.* (2009) who proved that, cooling treatment is preferable for many advantages, since seed being cooled at silo- chamber retain the temperature during the season of storing and keep safe from harmful insects that could be introduced in silo .They also demonstrated that, cooled grain is naturally preserved and pests are not able to develop and damage grain quality and quantity losses are lowered , with no contamination of products, or environment . Concerning high temperature, the obtained results also agreed with (Alice *et al.,* 2013) who proved that insects die by exposing to high temperature degrees, because their limited physiological ability to thermo regulate. Higher temperature presumably raised the metabolic rates of exposure insect caused fleetly mortality from raised stress due to low O_2.

Table 1. Effect of extreme temperatures and time of exposure on mortality of *C.maculatus* adults.

Mortality percentages after exposure time (min) at various Temperature degree.					
Temperature degree ºC / Time of exposure (min)	50	60	70	-5	-10
5	22.13	35.01	43.3	39.3	46.0
10	31.01	38.00	54.7	41.0	53.3
15	42.64	49.0	60.7	50.1	75.6
20	45.2	52.6	84.3	65.6	92.3
25	53.7	56.6	97.6	90.3	100
30	64.5	64.3	100	100	
35	71.3	79.0			
40	96.0	100			
50	100	100			
Control	2.3				

Effect of tested temperatures on immature stages of *C . maculatus* :

Table (2) showed the effect of tested temperature on egg development of *C. maculatus* on faba bean at different exposure times. Results in Table (2) revealed that, egg hatchability amounted in 89.52% for untreated control (at room temperature). Exposure at 50,60,70,-5 and -10ºC) for 5 min. resulted in decreasing the hatchabilty to 77.0%, 63.7%, 53.5%, 48.6% and 36.7% respectively. The hatchabilty showed its end point (0.0) hatchabilty at 90,60,45, and 30 min resp. when exposure temperature were 50,60,70,-5 and -10ºCrespectively.

It worth mentioning that, the effect of low temperature was higher and clearly on *C. maculatus* eggs hatching than high temperature, So, the degree of -10 succeeded to preventing any hatch and egg development after 30 min. of exposure time. These results agreed with (Alder 2003) who demonstrate that eggs of some stored grain insects were killed rapidly by low temperature

Table 2. Effect of extreme temperature on hatchability percentage of eggs of *C.maculatus* on faba bean seeds.

Exposure time (min)	Hatchability (%) of eggs at tested temperatures				
	50ºc	60 ºc	70ºc	-5ºc	-10ºc
5	77.0	63.7	53.5	48.6	36.7
10	73.3	63.0	51.7	48.0	32.0
15	70.7	60.1	50.0	43.7	31.6
30	58.0	40.7	31.0	14.3	0.0
45	41.6	25.3	0.0	0.0	
60	22.3	0.0			
75	3.01				
90	0.0				
Control	89.52				

Table (3) revealed the effect of tested temperature and different exposure times on the emergency of *C.maculatus* adults from infested faba bean with eggs after its hatch.

Data showed that, mean emergence percentages from infested faba bean was 54.41%,49.01%,39.8%,32.82% and 22.06% at 50,60,70,-5 and -10ºC compared with 98.81% for the untreated control. So, the degree of -10 ºC succeeded to prevent any emergent adults at 30 min. of exposure time. Another tested temperature (50, 60, 70, and -5ºc) inhibited the emergency after 90, 60, 45 and 45 min. respectively compared with untreated control (Table 3). Data proved also that, with raised of temperature degree and exposure times was apparition of insects from infested samples decreased. These results agreed with (Alice *et al.*, 2013) they reported that with increasing the exposition time to high temperature The number of brunched adults decreased drastically. They proved that, low temperature Reduce insect development and killed large number of immature stages of stored grain insects.

Table 3. Effect of tested temperature and different exposure times on the emergency of *C.maculatus* adults from infested seeds bearing eggs.

Tested temperatures degrees															
	50			60			70			-5			-10		
Eposure time(min)	Mean No.of emerged adults	Emergency		Mean No.of emerged adults	Emergency		Mean No.of emerged adults	emergency		Mean No.of emerged adults	emergency		Mean No.of emerged adults	Emergency	
		%	Mean		%	Mean		%	Mean		%	Mean		%	Mean
5	70.9	83.7		61.3	75.4		44.6	64.92		39.7	65.08		16.7	39.76	
10	65.0	81.93		53.0	75.0		37.3	56.51		21.0	41.42		11.0	29.97	
15	62.6	78.48		50.7	71.43		26.30	43.11		16.30	32.6		7.4	18.5	
30	44.8	72.13		21.3	61.76		11.7	34.41		2.50	25.0		0.0	0.0	
45	31.6	65.96	54.41	10.2	10.42	49.01	0.0	0.0	39.8	0.0	0.0	32.82			22.06
60	17.4	47.22		0.0	0.0										
75	4.9	5.86													
90	0.0	0.0													
Cont.	83.60	98.81													
F. value	2.41			5.71			9.66			4.17			2.76		
L.S.D	0.47			1.14			0.39			0.22					

With regard to the results of table (3), is evident that tested temperature have effected role on emergency of the adults, mean number of emergence and emergence percentage for tested exposure times were significantly decreased with increasing of temperature It is from this investigation that high and low temperature offered a great opportunity for successful protection of stored seeds against assault by *C.maculatus* and provided efficacy protection of small and medium storage of grains and does not require any fiscal parlaying.

Data in table (4) showed the reduction ratios of adult emergence of *C.maculatus* from immature stages exposed to tested temperature and exposure times . Data revealed that *C.maculatus* eggs were more susceptible (least tolerant) to tested temperature and exposure times than other stages. It gives about complete reduction after 75 min at all tested high temperature and at 45 & 30 min. at -5 and -10ºC respectively.

For larval stage (2-weeks-old), after 60 min, reduction ratios at 50,60,70 and -5ºC were 52.2,80.0,100% and 100% resp., meanwhile, the degree of --10 ℃ succeeded to prevent any emergence for all immature stages at 45 min. The tolerance of this aged was intermediate between the other stages.

Results proved also that, exposure to 75 min. at 70 ºC and 60 min and -5ºC succeeded to prevent any emergency, the reduction ratios gave 100% inhibition of all tested stages. In conclusion, tested heat and cold tolerance of *C.maculatus* , the order were :egg< larvae< pupae. These results agreed with Loganathan *et al.* (2011) which proved that, decreased of apparition were increased in parallel with high of temperature degrees and exposure times of *C.maculatus*, also with Mohamed and Ismail (1996) found complete control of all immature stages of *C.maculatus* was achieved by exposing infested faba beans to 70 degrees (for 20 minutes) . Also, it could be mentioned that, a much higher temperature much low temperature and increased exposure time were needed to get full control of the tested insects. Also, adequacy of temperature to control *C.maculatus* in inside layers of seeds is lower than of those insects on the surface of the faba bean,. SO, full mortality of *C.maculatus* feeding within seeds needed longest time compared with freely exposed stages (adults). In conclusion, extreme temperature have affected role in seeds crops pest. So results showed that the investigated treatment may be lead to decrease in the economic losses correlated with minimize infestation by *C.maculatus of faba bean* seeds in the storage. Finally, the temperature and exposed times important to detersive the faba bean and no significantly difference effected on the cooking time of faba bean. Generally, low temperature does not adverse effect on seeds. Different approach have been used for heat and cold disinfestations in new system of seeds

storage, the choice of which process is suitable will based on local costs of energy, construction and powering costs Longanthan *et al.* (2011). Finally, it could be reported that, pods of pulses should be harvested as soon as they mature and the seeds are sun dried or stored in refrigerated conditions in air tight beetle-proof containers. This way of physical control will ensure that the quality of grain entering the storage means does not worseting over time. These measures are eco-friendly environmentally safe and cost effective too.

Table 4. Reduction ratios of adult emergence of *C.maculatus* adults from immature stages exposed to tested temperatures and different exposure times (min)

Reduction percentage of adults emergence at various tested temprature															
	50			60			70			-5			-10		
Exposure times(min.)	E	L	P	E	L	P	E	L	P	E	L	P	E	L	P
5	28.6	15.3	13.2	44.0	23.7	22.6	53.0	39.3	34.0	69.0	45.1	54.0	81.0	66.7	60.0
10	30.2	17.1	15.2	51.0	24.1	22.9	53.6	42.8	42.3	71.6	51.1	62.0	90.0	76.7	74.6
15	41.3	26.6	21.0	60.3	41.1	35.0	62.3	56.4	51.0	76.3	67.0	69.3	90.7	81.3	77.0
30	61.6	29.7	21.6	61.0	57.4	37.9	79.0	65.2	57.3	81.0	74.7	71.0	100	93.0	81.3
45	79.0	41.2	33.7	75.0	69.7	56.1	96.0	90.0	69.0	100	100	81.0		100	100
60	84.8	52.2	46.6	88.3	80.0	61.0	98.0	100	94.0			100			
75	98.8	94.7	67.8	100	100	100	100		100						
90	100	100	100			100									

E:Egg L:Larvae P:Pupae

Technological properties

Table 5 summarize the physical properties of the faba bean samples Data indicated that there were non-significant differences ($p \leq 0.05$) between samples 1, 2 and 3 in 100 seed weight. The average ranged from 88.13 g to 90.43 g. Density (g/cm^3) recorded 1.23, 1.22 and 1.20 for samples 1, 2 and 3 respectively. Seed coat percent ranged from 11.45 % to 11.57 % while the average seed cotyledons percent decreased non significantly ranged 77.12 % to 83.30 %. It may attributed to the thermal treatment. Also there were no significant difference ($p \leq 0.05$) between two treated samples (low temperature & high temperature) in hydration coefficient percent of faba bean seeds after soaking. The lowest value was (111.67%) for control.

Attia and Mohamed (2007) mentioned that physical properties of some verities of Egyptian faba bean for density ranged from 1.97 to 2.53, 100 seed weight were 74.8 g (Misr 1), 73.0 (Giza 843), 81.6 (Giza 3), 74.8 (Giza 40) and 104.3 (Giza 716). Also Imbibed water (%) after soaking ranged from 99.59 to 124.86 while cotyledons % were ranged from 79.47to 97% seed coat % was ranged 10.39 to 12.75%.

Table 5. physical properties of the control and treated faba bean seeds.

Parameters	**(1)**	(2)	**(3)**
100 seeds weight(g)	90.43± 3.83[a]	89.73 ± 6.20 [a]	88.13± 3.50[a]
Density	1.23± 0.05[a]	1.22 ± 0.02[a]	1.20 ± 0.08[a]
Seed coat content %	11.57± 0.28[a]	11.56 ± 0.27[a]	11.45 ± 0.27[a]
Seed cotyledons content %	80.18 ± 2.71[a]	77.12 ± 1.68[a]	83.30 ± 4.38[a]-
Hydration coefficient %	115.44 ± 0.07[a]	114.37 ± 1.94[a]	111.67 ± 0.61[b]
Length mm	12.20 ± 0.19[a]	11.80 ± 0.15[a]	13.00 ± 0.16[a]
Width mm	8.80± 0.08[a]	8.20 ± 0.13[a]	8.40 ± 0.15[a]
Thickness mm	3.80 ± 0.08[a]	3.40 ± 0.05[a]	3.60 ± 0.05[a]
L*	63.42 ± 4.81[a]	44.53 ± 5.5 [b]	50.69 ± 0.43 [b]
a*	6.05± 1.9 [c]	12.62 ± 0.54[a]	9.09 ±1.66[b]
b*	30.91 ± 0.07[a]	21.69 ± 0.74[c]	26.49 ± 0.26[b]

1-treated faba bean seeds at -10ºC for 45 min. 2-treated faba bean seeds at 60ºC for 70 min. 3-untreated faba bean seeds (Control). Means in the same column having different superscript letters are significantly different p≤ 0.05.

Effect of heat treatments on dimensions faba bean seeds

Dimensional properties of faba bean seeds were given in Table (5). The average length of faba bean seeds was 12.2, 11.8 and 13.0 mm, the width was 8.8, 8.2 and 8.4 mm and thickness 3.8, 3.4 and 3.6 mm for samples 1,2 and 3 respectively. The decrement of seed dimensions may be attributed to the decrease of moisture content from 10.89 % (control) to 9.43% (Table 6). Although no significant difference between three samples was found Shoughy and Elzun (2014) mentioned that the length, width and thickness of faba bean seeds at 12.5 % moisture content were 13.6, 10.1 and 6.29 mm respectively.

The visual appearance is considered one of the best important characters of overall acceptability by the consumers. Color of the surface seeds properties of the raw dry three samples were given in Table 5. The L* values of sample 2 significantly decreased ($p \geq 0.05$) indicating that seeds were darker than sample 3 while sample 1 was given the highest L* value. a* value of sample 1 significant lower (6.05) than sample 2 (12.62) and 3 (9.09). Concerning b* values the highest b* value was in sample (1) 30.91 compared with sample (2) 21.69 and sample (3) 26.49. The differences

between seeds color may be attributed to difference heat treatment of seeds which affected the phenolic compounds containing the faba bean seeds (Table7).

Table 6. chemical composition and Minerals content of the control and treated faba bean samples (% dry weight).

Parameters (g/100 g)	(1)	(2)	(3)
Moisture	10.59 ± 0.29^{a}	9.43 ± 0.40^{b}	10.89 ± 0.05^{a}
Protein	26.62 ± .018^{a}	25.78 ± 0.57^{a}	25.40 ± 0.16^{a}
Fat	2.42 ± 0.10^{a}-	2.38 ± 0.17^{a}-	2.73 ± 0.35^{a}
Fiber	7.29 ± 0.16^{b}	7.01 ± 0.26^{b}	7.98 ± 0.06^{a}
Ash	2.86 ± 0.56^{a}	3.25 ± 0.01^{a}	3.23 ± 0.64^{a}
Total carbohydrates	50.22 ± 0.89^{b}	52.05 ± 0.32^{a}	49.77 ± 0.45^{b}
Minerals (mg/100g)			
Ca	103.38±9.25^{a}	106.91±7.763^{a}	108.94±5.13a
K	718.00±4.30^{a}	648±4.2^{b}	724±8.00^{a}
Mg	337.22±13.79^{a}	346.22±.86^{a}	331.68±5.67^{a}
Na	33.00±6.98^{a}	30.00±0.92^{a}	35.00±0.16a
P	379.00±5.25^{a}	312±4.65^{a}	386±6.60^{a}
Fe	5.92±0.306^{a}	6.07±0.19a	5.70 ± 0.26^{a}
Zn	6.58±.227^{a}	6.71±.43^{a}	6.20±.37^{a}
Cu	17.16±0.15^{ab}	17.95±0.92^{a}	16.73±0.18^{b}
Mn	12.18±0.78^{a}	12.36±0.20^{a}	12.70±0.17^{a}

1-treated faba bean seeds at -10^{o}C for 45 min. 2-treated faba bean seeds at 60^{o}C for 70 min. 3-untreated faba bean seeds (Control). Means in the same column having different superscript letters are significantly different p≤ 0.05.

The chemical composition for the three faba bean samples shown in Table (6). Results revealed that there were significant differences in moisture content. Values ranged from 9.43 to 10.89%. The range in protein content extended from 25.40 to 26.62 % and the fat content ranged from 2.38 to 2.73 % respectively with non-significant differences among all samples. These results were in agreement with those obtained by Attia and Mohamed (2007) and Mohamed *et al.* (2011). Carbohydrate ranged from 49.77 to 52.05% with significant decrease in sample 1 and 3 compared with sample 2. On the other hand, ash content showed slight increase for sample 2 and 3 compared with sample 1. This can be attributed to decrease in some components like carbohydrates. The obtained results were in agreement with those obtained by Mohamed *et al.* (2011) who mentioned that ash of faba bean ranged from 3.24 to 3.58% which confirmed the results of Attia and Mohamed (2007) who found that ash content ranged from 3.11 to 3.95%. While fiber content, a significant difference was found between samples 3 (7.98%) and two other samples 1,2 (7.29%) and (7.01%) respectively. This

be due to the effect of the insects which penetrate the seed hull for feeding on the chemical components.

Minerals content

Mineral content of seeds are presented in Table 6. Calcium, potassium, magnesium, sodium, phosphorus and iron content were analyzed for three faba bean samples. Calcium content for sample 3 was found to be 108.94 mg/100g, which was significantly higher ($p \leq 0.05$) than the value 103.38 and 106.91 mg/100g obtained for sample 1 and 2. Potassium content for three samples were found to be range from 648 to 724 mg/100g. These values were similar with the value 649 mg/100g reported by Khalil (2001). Magnesium content for sample 1 was found to be 337.22 mg/100g, while for sample 2 it was 346.22 mg/100g and sample 3 recorded 331.68 mg/100g. There were non-significant differences between the magnesium content of the three samples. Sodium content of sample 1 was found to be 33.0 mg/100g, while for sample 2 30 mg/100g and sample 3 it was (35.0 mg/100g). The obtained values of sodium content for three samples were similarly within the range of 26.6 to 35.94 mg/100g reported by Balla (2004), Phosphorus content for samples 1,2 and 3 were found to be 379.0, 312 and 386 mg/100g. Iron content for sample 1 was found to be (5.92 mg/100g), while for sample 2 it was (6.07 mg/100g) and sample 3 it was (5.70 mg/100g). There were non-significant differences between three samples. The values of three samples were similarly within the range of 5.97 to 6.47 mg/100g reported by Balla (2004).

The contents of Zinc (Zn), copper (Cu) and manganese (Mn) of fababean samples were ranged from 6.20 to 6.71 mg/100g, 16.73 to 17.95 mg/100g and 12.18 to 12.70 mg/100g.

The obtained results showed a decrease in the amounts of Ca, K, Na, P, Fe and Mn, while an increase in the amount of Mg, Zn and Cu showed an increase due to the infested material exposured to -10 ℃ and 60 ℃ for 45 and 70 min. respectively. The obtained results were in agreement with those of Khalil (2001) who reported that faba bean seeds contained 649 mg K/100g sample. Sodium content was in line with Balla (2004) who found a value ranged from 26.6 to 35.94 mg/100g sample. The same author (2004) reported that faba bean contained Fe in the range of 5.97 to 6.47 mg/100g the decreasing of some minerals may be due to the insect consumption during infestation period.

Table 7. protein digestibility and bioactive components of control and treated samples.

Parameters	(1)	(2)	(3)
Protein digestibility %	78.53±4.68[b]	90.86±4.88[a]	88.30±8.12[a]
Tannins (mg/100g)	300.20±1.05[b]	220.00±1.00[c]	316.00±1.00[a]
Total phenols (mg/100g as galic acid)	81.01±2.36[a]	66.65±0.69[b]	80.18±0.85[a]
Phytic acid (mg/100g)	844.00±1.00[b]	546.37±4.46[c]	892.67±0.57[a]

1-treated faba bean seeds at -10ºC for 45 min. 2-treated faba bean seeds at 60ºC for 70 min. 3-untreated faba bean seeds (Control). Means in the same column having different superscript letters are significantly different p≤ 0.05.

In vitro Protein digestibility (IVPD): The Protein digestibility was determined to provide the most satisfactory indication of seed utilization. The result was shown in Table (7). The mean value IVPD of samples 1, 2 and 3 were 78.53, 90.86 and 88.30% respectively. There was a significant difference (P ≤ 0.05) between the sample (1) and other two samples (2 and 3). The highest (IVPD) was value for sample 2 while the lowest value was for sample (1). This may be attributed to the thermal treatment which improve the quality of food legume due to reduction in anti-nutrient Ertop and Bektaş (2018).

Bioactive components:

The Bioactive components of tested seeds are presented in Table 7 The mean value of tannins content of faba bean samples ranged from 220.00 to 316.00 mg/100g. Sample 3 contained tannins significantly (p≤ 0.05) higher than that in others two samples 1 and 2. The amount of tannins in sample 3 was 316 mg/100g while sample 2 had the lowest value 220 mg/100g. Total phenols content were found to be 81.01 and 80.18 mg/100g (as galic acid) for samples 1 and 3, while for sample 2contained 66.65 mg/100g (as galic acid). There were a significant (p≤ 0.05) differences between treatments. A highly significant decrease was reported in sample 2 compared with other two samples. The mean phytic acid contents of faba bean samples under study ranged from 546.37 to 892.67 mg/100g. Sample 3 had the highest value (892.67mg/100g), while sample 2 showed the lowest one (546.37 mg/100g) Table **(**7**)**. From the above mentioned data, it could be concluded that heat treatment resulted in improved Protein digestibility and decreased the anti nutritional factors. Also The infestation of untreated faba bean seeds after six month storage was 12% at room temperature while

treated faba bean samples n't happened any infestation during storage six month and no changes in chemical composition after this time.

Table 8. Hydration coefficient, cooking quality and T.S.S of the control and treated samples.

Parameters	(1)	(2)	(3)
Hydration coefficient after cooking %	177.47 7.2 [a]	168.98 ± 18.39 [a]	179.81 ± 5.71 [a]
Cookability %	86.67 ± 15.27 [a]	96.67 ± 5.77 [a]	93.33 ± 11.5[a]
Total soluble soiled % (T.S.S)	11.99 ± 0.81[a]	11.52 ± 0.55 [a]	11.70 ± 0.03 [a]

1-treated faba bean seeds at -10ºC for 45 min. 2-treated faba bean seeds at 60ºC for 70 min. 3-untreated faba bean seeds (Control). Means in the same column having different superscript letters are significantly different p≤ 0.05.

Cooking quality

Total soluble solids are the best one of the quality indicators of the cooked faba bean seeds. Guzel and Sayar (2012).

Results of hydration coefficient, Cookability and T.S.S of faba bean are given in Table (8) the data revealed that non-significant differences (P≤ 0.05) between treatments in hydration coefficient of cooked bean.

The average of the hydration coefficient ranged from 168.98% to 179.81% for cooked bean while the average of cookability percent ranged from 86.67% to 96.67%. Sample 2 had the highest value (96.67%) followed by sample 3 (93.33%) cooling treatment 1 resulted in the lowest value (86.67%). Concerning to T.S.S no significant differences were found between the three treated samples after cooking which ranged from 11.52 to 11.99 % respectively. This results agreement with Mohamed *et al.* (2011) who reported that stewing % of faba bean dry seeds was ranged from 85 to 100% and amounts of total solids of faba bean dry seeds were ranged from 8.50 to 15.77%**.** From the above mentioned data it could be concluded that cooling treatment resulted in lowest cookability while heating resulted in maximum cookability.

Table 9. sensory evaluation of cooked faba bean.

Parameters	(1)	(2)	(3)
Color	4.15 ± 0.74[a]	3.5 ± 0.53[a]	3.95 ± 0.76[a]
Taste	3.75 ± 0.79[a]	4.1 ± 0.52[a]	3.55 ± 0.69[a]
Odor	4.1 ± 0.58[a]	4.1 ± 0.32[a]	3.9 ± 0.57[a]
Appearance	4.0 ± 0.67[a]	4.0 ± 0.67[a]	3.9± 0.58[a]
Total score	16.00±2.31[a]	15.70±1.69[a]	15.30±2.26[a]

1-treated faba bean seeds at -10ºC for 45 min. 2-treated faba bean seeds at 60ºC for 70 min. 3-untreated faba bean seeds (Control). Means in the same column having different superscript letters are significantly different p≤ 0.05.

Sensory evaluation of cooked faba beans is one of the important characteristics which reflect their acceptability. Table (9) showed the mean values of organoleptic characteristics scores (color, taste, odor, appearance and the averages total scores) of cooked faba beans. The obtained results indicated that there were no significant differences in all sensory parameters among the treatments. The highest total scores are belonged to sample 1 followed by sample 2 then sample 3.

CONCLUSIONS

From the obtained results it could be concluded that the influence of both heat or cold treatments on the mortality rate of tested insect was positively correlated with the time of exposure, the increase of heat or cold temperature and the stage of insect.

Protein digestibility was increased as a result of high temperature treated sample while bioactive compounds (phytic acid, tannins and total phenols) decreased. The color of high temperature treated seeds was darker than other samples. High temperature improvement the cookability of faba bean seeds. Finally, it could be concluded that using this methods to prevent faba bean seeds from infestation by C.maculates.

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استخدام المعاملة الحرارية للقضاء على حشرة خنفساء اللوبيا التي تصيب الفول البلدى اثناء التخزين وتأثيرها على الخواص الفيزيوكيميائية والتكنولوجية

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تعتبرعمليات ا لتطهيرالحراري إحدى طرق مكافحة الحشرات تناولت الدراسة فى هذا البحث إستخدام درجات حرارة مرتفعة ومنخفضة حيث تم استخدام درجات حرارة مرتفعة50،60، 70م ودرجات حرارة منخفضة -5 و -10م وذلك لمدد زمنية 5،10،15،30 ، 45 ،60،75 ،90،95 دقيقة ، وذلك لمعاملة كلا من البيض واليرقات والعذارى والحشرات الكاملة لحشرة خنفساءاللوبيا وذلك لتحديد نسب الموت المختلفة للوصول الى درجة الحرارة ومدة التعرض التى عندها يحدث اختزال كامل وعدم خروج خلفة جديدة. كما تم عمل دراسات تكنولوجية على الفول المعامل بدرجة 60م لمدة75 دقيقة وكذلك علي درجة حرارة -10 لمدة 45 دقيقة .

أظهرت النتائج الاتى :-

-تزداد نسب الموت كلما زادت درجات الحرارة ومدة التعرض.

- اظهرت الحشرات الكاملة والبيض حساسية كبيرة عند التعرض لدرجات الحرارة المستخدمة مقارنة باليرقات بينما كانت العذارى أكثر تحملا لدرجات الحرارة المستخدمة.
- كانت نسب الموت عالية جداعلي درجات حرارة60م لمدة75 دقيقة وكذلك -10 لمدة 45 دقيقة عند مقارنتها بدرجات الحرارة الأخرى.

ومن ناحية أخرى، تم أيضا دراسة الخواص الفيزيوكيميائية والتكنولوجية على الفول المعامل (60 م لمدة 75 دقيقة و -10 لمدة 45 دقيقة) ومقارنتها بالكنترول.

وأظهرت النتائج ما يلي :-

- لا توجد فروق معنوية بين عينات الفول المعاملة بالحرارة والبرودة فى نسبة البروتين بالمقارنة بالعينة غير المعاملة (الكنترول).
- كانت هناك فروق معنوية فى نسبة التشرب بعد النقع لمدة 12 ساعة بين العينات المعاملة والكنترول.
- ولوحظ زيادة دكانة اللون للعينة المعاملة بالحرارة عن العينة المعاملة بالبرودة والكنترول.
- نسبة القابلية للطهى ازدادت فى العينة المعاملة بالحرارة حيث كانت96,67% مقارنة بالمعاملة بالبرودة والكنترول (86,67 و93,33%) على التوالى.
- وازدادت نسبة كفاءة هضم البروتين فى العينة المعاملة بالحرارة بينما انخفض محتوى المركبات الفيتوكيميائية (التانينات-الفنيولات وحمض الفيتيك).
- وأظهر التقييم الحسى عدم وجود فروق معنوية بين عينات الفول المطهى بالنسبة للعينات المعاملة بالحرارة العاليةاوالمنخفضة والغيرالمعاملة (الكنترول).

واخيرايمكن القول بأن المعاملات الحرارية للبقوليات تعتبر من أفضل الطرق الفيزيقية المتبعة لقتل حشرات البقوليات وأطوارها وبالتالى الحفاظ على البذور سليمة مع المحافظة على صفاتها الفيزوكيميائية ولم تسبب فقدا فى نسبة البروتين.