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PHYSICAL, MECHANICAL AND BIOLOGICAL PROPERTIES OF SESAME PELLETED SEEDS

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ABSTRACT

Sesame is an important crop for the production of oil especially in newly reclaimed lands of Egypt. A machine for pelleting the small and light sesame seeds was designed and constructed in a laboratory scale to change the shape and size of sesame seeds enlarging the seed by a pellet which more heavier, size and rounder to facilitate sowing sesame seeds by planters. Some of the most important operational parameters were investigated, whereas, rotating speed of the pelleting pan affected the physical pellet properties. Rotating speed of 30 rpm showed the greatest pellet weight, sphericity percentage and true density. Out of three different quantities (100, 250 and 500g) of seeds per run during pelleting process, 250 g showed maximum pellet axial dimensions, pellet volume and weight. Ratio between pelleting material added to the pan during run and seed quantity was considered, whereas, ratios of 5:1, 10:1 and 20:1 were investigated. Maximum pellet axial dimensions and maximum pellet sphericity percentage were obtained when a ratio of 20:1 was applied. The lowest adhesive material concentration (5 %) showed a distinguished pellet size, volume and weight when compared to higher concentration. On the other hand, small quantity of 50 mm^3 adhesive solution per 500 g pelleting material gave maximum pellet volume and weight, however, the maximum quantity of (150 mm^3/ 500 g pelleting material) gave the greatest sphericity percentage of 76.33%. Ratio of pelleting material components (pentonite / lime) showed that a ratio of 75% Pentonite: 25% lime gave maximum pellet dimensions, volume and weight, while a ratio of 0% Pentonite: 100% lime showed maximum sphericity percentage. Maximum contact stress and cutting strength decreased with increasing the geometric diameter of the pelleted seeds for all investigated parameters. Both germination and vigor percentages of pelleted seeds were decreased when compared with untreated seeds. Meanwhile, germination rate of pelleted seeds increased when compared with untreated seeds. Therefore, germination and vigor of high quality sesame seeds did not enhanced by pelleting process, while rate of germination remarkably increased when seeds were pelleted perior planting. Pellet dimensions, volume and sphericity are the major variables had a remarkable relation with germination and vigor percentages.

Keywords: Sesame, *Sesamum-indicum*, Seed, Pelleting, Germination, Vigor.

INTRODUCTION

In Egypt, sesame is considered one of the most important oil crop and has a great potentiality for human consumption, food, medicine industries and animal feeding. The area of sesame has increased from 26 thousand fed in 1984 to 68 thousand fed in 2005 (Agricultural Statistics, 2006). Generally, pelleting aimed to develop a sensitive sesame seed planting method as an alternative to the traditional broadcast sowing methods. Seed enhancement technology has a central objective to further improve seed performance under very specific regimes and with certain planting equipment. While seed pelleting is recommended from the standpoint of seed shape and size, so that it becomes larger, heavier, smoother, more uniform and rounder and thus gives, better flow through the seeding mechanism and minimize the costs of field planting and thinning operation (Copeland and McDonald, 1995), and safety standards for workers, seed protection, seed germination percentage, uniform plant establish and yield (Tilcher, 2005; Halmer, 2005; Abdel-Tawab, 2005 and Shewmaker *et al* 2002). Small rotating drum coaters are particularly useful for small and light seeds pelleting when it is difficult to use planting machines (Sahhar *et al* 2006 and Scott *et al* 1997). However, it was found that coating treatment acted negatively on seed germination when compared to uncoated seeds (Barut and Cagrgan, 2006). On the other hand, pelleted seeds exhibited the highest germination percentage when pelleted seeds were used for field planting in Turkey, while planting pelleted seeds with a pneumatic spacing planter resulted in higher emergence rates and smoother sowing compared with the traditional broadcast sowing method (Dogan *et al* 2005). Applying growth-promote agent and biocontrol bacteria strains to seed were evaluated for its capacity for biological control and growth promotion. Seed pelleting with such materials was attempted to increase the seed size and to improve the stability and effectiveness of biocontrol capacity (Pyv *et al* 2006). Same attitude was applied when *Trichoderma harzianum* was used in coating sesame seed for biocontrol of *Macrophomina phaseolina*. The pathogen causing charcoal rot in sesame, whereas, significant differences in plant death were observed (Pineda, 2001). Also, three isolates of *Trichoderma viride* were applied coating to sesame seed to biocontrol *Fusarium and Rhizoctonia* pathogens (Chung and Choi, 1990). Information on physical, mechanical and biological properties of sesame pelleted seeds is needed for the design of planting machines , also for maintaining high seed quality during pelleting processes. Therefore, the objective of this work is to determine the effect of pelleting process variables on: 1) the physical properties of pelleted seeds (size, shape, volume, sphericity, weight and density); 2) the mechanical properties of pelleted seeds (static coefficient of friction, natural angle of repose, maximum contact stress, cutting strength and pellet hardness), 3) the biological properties (germination and vigor percentages and germination rate) of pelleted seeds processed by pelleting machine, 4) Determining factors that had the most relation with seed quality.

MATERIALS AND METHODS

Seed material and pelleting machine:

All pelleting runs were aimed sesame seeds (Shandweel 3) obtained from Oil Crop Research Inst., Agricultural Research Center. This work was accomplished by using an experimental model of seed pelleting machine which designed, manufactured, and operated through a co-operation between Agronomy Dept. and Agric. Eng. Dept., Fac. of Agric., Ain Shams Univ. Full description of the designed machine for seed pelleting (Fig. 1) was demonstrated in detail previously (Sahhar *et al* 2006).

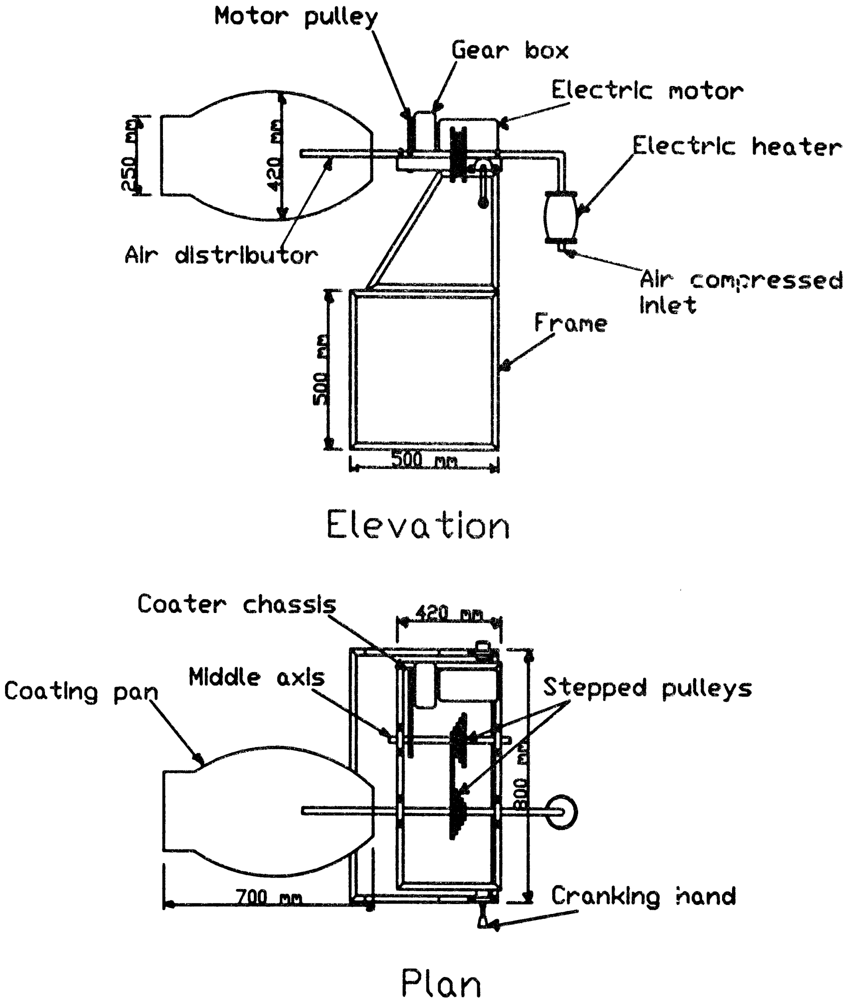

Fig. 1. The designed seed pelleting machine

Investigation procedure:

Variables of pelleting process which affect the quality of seed pelleting were investigated by conducting numerous simple experiments. The investigated variables included the rotational speed of the pelleting pan (15, 30, 45 and 60 rpm), the quantity of seeds added per run (100, 250 and 500 g) , the ratio of pelleting solid materials to seed (5, 10 and 20 times), the effect of levels of adhesive concentration (dissolved Arabic gum) (5, 10 and 20% weight/ volume), the quantity of adhesive solution added per pelleting solids (50, 125 and 150 mm^3/ 500 g pelleting material) , and substituting varying quantities (0, 25, 50, 75 and 100%) of lime (Calcium carbonate) for Pentonite

(Aluminum silicate) to determine which conditions of pelleting process were most susceptible to the hardness of pelleted seeds.

Investigation conditions:

As each experiment was conducted, other factors not under investigation were adjusted at 45 rpm for rotating pan speed, 100 g seed quantity per run, (5:1) pelleting material weight : seed weight, 20 % adhesive concentration, 125 mm^3 adhesive quantity/ 500 g pelleting material, 100% Pentonite pelleting material, 0.65 mm^3/ S rate of adhesive spraying, 15 min. drying time for produced pellets, 40°C air temp. for drying the produced wet pellets and 20°pan incline angle.

At all levels of different variables, the pelleted seeds were used in these tests after discarding the fine material, unpelleted seeds and agglomerate pelleted seeds which were considered as inert matter.

The main calculations can be summarized as follows:

A) Physical properties of sesame pellets:

1- Pellet dimensions: the dimensions of the sesame pellets were measured in three directions using a caliper gauge (0.01 mm). The major diameter was the length of the pellet, the intermediate diameter was the width and the minor diameter was the thickness of the pellet. The minor diameter was taken perpendicular to the intermediate diameter. The caliper was held perpendicular to the direction of the dimension being measured. Dimensions were measured on 100 pellets of four replicates for each treatment:

2- Geometric mean diameter and volume

The average geometric diameter "Dg" and average volume "V" of pelleted seeds were calculated according to **Mohsenin (1986)** as follows:

$$Dg = (a.b.c)^{1/3} \quad , V = \frac{1}{6} \Pi \, ab^2$$

Where: a = average major diameter in mm; b= average intermediate diameter in mm and c = average minor diameter of the raw and pelleted seed in mm.

3- Sphericity:

The sphericity index, "Sp" was calculated for pelleted seeds according to **(Mohsenin, 1986)** as follows:

$$Sp = \frac{(a.b.c)^{1/3}}{a} \times 100$$

4- Weight and true density (unit density):

The average weight of sesame pellet was recorded and then the true density (unit density) of the pelleted seeds was determined through dividing the average mass of pellet by its average computed volume.

B) Mechanical properties of sesame pellets:

1- Natural angle of repose

The natural angle of repose for a pelleted seed sample was measured using a wooden frame full of pelleted seed sample. It was mounted on a tilting top drafting table. The table top was tilted until the pellets began to move, leaving an inclined surface. The angle of the inclined pelleted seed surface was measured as the angle of repose for the particular sample "ϕ".

2- Static coefficient of friction

The static friction coefficient "μ" of pelleted seeds is equal to the tangent of the internal friction of the pellets. A pellet sample of (100 g) was used to measure the angle "α" at which the pellets sample start to slide down the slope on a tilting steel surface. The following equation was used to calculate the static coefficient of friction: $\mu = \tan \alpha$

3- Maximum contact stress, cutting strength and pellet hardness

Maximum contact stress "S_{max}", cutting strength "S_{cu}" and hardness "Hp" of sesame pellets were computed throughout measuring the compressive, cutting and penetrating forces respectively by using (A digital force gauge - Shimpo Model FGC-50-range up to 500 N, Made in Japan) divided by area according to the following equations **(ASA E, 1996)**:

$$S_{max} = \frac{1.5\ F_{co}}{\prod a.b}$$

$$S_{cu} = \frac{4F_{cu}}{\Pi\ Dg^2}$$

$$Hp = \frac{4Fp}{\Pi\ d^2}$$

Where: F_{co} registered compressive force in N, F_{cu}: registered cutting force in N, Fp: registered penetration force in N, Dg: mean geometric diameter of sesame pellet and d: diameter of indentation in mm, a: Semi major axis in mm, b: semi minor axis in mm.

C) Biological properties of sesame pellets:

1- Germination percent of pelleted seeds:

Samples of 100 pellets in four replicates were germinated on rolled towel paper and incubated at 25°C for a period of 7-days **(ISTA, 1996)**. Only 2-6 mm pellet size was used in this test, germination percentage "Gp" was calculated as follows:

$$Gp = \frac{No.\ of\ \ germinated\ \ pellets}{Total\ \ pellets}\ x\ 100$$

2- Vigor percent of pelleted seeds:

Samples of 100 pellets in four replicates were germinated in coarse sand (3 cm depth) and incubated at 25°C for a period of 7-days **(ISTA, 1996)**. Only 2-6 mm pellet size was used in this test, vigor percentage "Vp" was calculated as follows:

$$Vp = \frac{No.\,of\ \ germinated\ \ pellets}{Total\ \ pellets}\ x\ 100$$

3- Germination rate of pelleted seeds:

Germination rate (Gr) were calculated by counting number of seedlings emerged during germination period after 4 days from planting up to four counts (2days intervals) **(ISTA, 1996)**.

$$Gr = \frac{a + (a + b) + (a + b + c) + ...}{n(a + b + c + ...)}$$

Where: a = first count of germinated seed, b= second count, c= third count and n = number of counts

Statistical analysis

Treatments were accomplished according to complete random design in four replicates. The data were analyzed according to (SAS, 1988). Means were compared using least significant difference (LSD 5%), also backward multiple regression analysis was performed according to (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of rotational speed of pelleting pan on some physical properties of sesame pelleted seeds

Data presented in Table (1) indicate that pelleted seed dimension varied significantly as response to pan rotational speed except major diameter, consequently, pellet volume varied approx. from 19.89-28.88 mm^3. It was found that the major dimension of pellet (where the length of the seed within the pellet was at that position showed the longest dimension) varied from 4.14 mm to 4.38 mm. Intermediate length (where the width of the seed within the pellet was at that position) varied from 2.87 mm to 3.57 mm. Meanwhile, minor dimension (where the thickness of the seed within the pellet was at that position) varied from 1.88 mm to 3.07 mm. It is noticeable that the three dimensions were lowest when 60 rpm was applied; on the other hand, the greatest values of the three dimensions were obtained when 30 rpm of rotational pan speed was applied during pelleting process. Speeds of 15 and 45 rpm gave in between values for the three dimensions. Seed volume before pelleting process (raw seed) measured 7.52 mm^3, while this volume enlarged to 19.89 mm^3 and 28.88 mm^3, when 60 and 30 rpm of rotational pan were applied, respectively. High speed of pelleting pan up to 60 rpm produced the smallest pellet volume. Since the aim of the study is to change the sesame seed dimensions which are small in measure and elliptical in shape, results obtained indicate that pelleting process caused seed length to change from a dimension of 3.50 mm to 4.38 mm, seed width enlarge from 2.03 mm to 3.57 mm and seed thickness enlarged from 0.90 mm to 3.07 mm. These enlargements in seed dimensions reached percentages, of 25.14, 75.88 and 241.11 for sesame seed length, width and thickness respectively. Results indicate that placing sesame seed in a pellet almost round was achieved, however, if the roundness of the produced pellet is not enough, causing problems during mechanical planting, a device for chafe seed against emery surface will be recommended to be attached or followed the pelleting machine. Trying to achieve a more roundness pellet by enlarging the pellet size is not preferable under the present investigation conditions.

Table 1. Effect of rotational speed of pelleting pan on some physical properties of sesame pelleted seeds.

Pan rotational speed (rpm)	Seed axial dimensions, mm			Geometric diameter mm	Volume mm^3	Sphericity %	Weight mg	True density mg/ mm^3
	Major	Inter-mediate	Minor					
Untreated seed	3.50	2.03	0.90	1.85	7.52	52.90	0.032	0.044
15	4.32	3.28	2.92	3.43	25.04	80.09	29.63	1.164
30	4.26	3.57	3.07	3.59	28.88	84.48	62.56	2.039
45	4.38	3.08	2.52	3.21	23.65	79.63	37.32	1.558
60	4.14	2.87	1.88	2.78	19.89	66.40	10.55	0.454
LSD at 50%	N.S	0.82	0.80	0.81	N.S	6.79	31.55	0.56

As seed pellet increased in its dimensions and accordingly the calculated volume, it was found that seed sphericity percentage increased in turn. Meaning that, increasing pellet dimensions increased pellet size and sphericity percentage (pellet become more round). Pellet produced at 30 rpm pan speed showed the maximum sphericity percentage. Although, applying 30 rpm pan speed gave the maximum sphericity percentage, it did not show superiority over the other two pan speed (15 and 45 rpm) since differences did not reach significance level. Applying speed of 30 rpm for pelleting pan gave the maximum pellet size; consequently, the produced pellet gave maximum weight of (62.56 mg). Accordingly true density mg/mm^3 of such pellet showed maximum value of (2.039 g/mm^3). The characteristics of the pellet produced under pan speed of 30 rpm showed the most promising and probable values.

Effect of seed quantity per run on some physical properties of sesame pelleted seeds

Different seed quantities were selected to investigate the machine response and properties of the produced pellets, data were tabulated in Table (2). Results show that increasing amount of seed per run up to 250 g increased the measured pellet dimensions to the values of 4.62 mm for major dimension, 3.45 mm for intermediate dimension and 2.94 mm for minor dimension. Ratio between pan size and amount of seeds to be placed in is one of the most important factor affecting the success of pelleting process. It is clear that all data obtained of both amounts of 100 and 250 g per run did not differ significantly, while, using amount of 250 g per run showed no significant increase upon amount of 100 and 500 g in all studied characters documented in (Table2).

Table 2. Effect of seed quantity per run on some properties of sesame physical pelleted seeds.

Seed quantity (g / run)	Seed axial dimensions, mm			Geometric diameter mm	Volume mm^3	Sphericity %	Weight mg	True density mg/ mm^3
	Major	Inter-mediate	Minor					
Untreated seed	3.50	2.03	0.90	1.85	7.52	52.90	0.32	0.044
100 g	4.37	3.07	2.47	3.15	23.51	72.80	42.24	2.286
250 g	4.62	3.45	2.94	3.58	30.50	77.50	91.05	3.170
500 g	4.31	3.16	2.76	3.32	23.85	78.24	75.68	3.374
LSD at 50%	N.S.	0.91	0.90	0.94	N.S	7.63	35.95	1.11

It is clear that average pellet volume of 23.51,30.50 and 23.85 mm^3, and average sphericity percentage of 72.8,77.5and 78.24% were obtained when the amount of feeding were 100, 250 and 500g seeds / run , respectively. Also it showed that the quantity of 250 g / run gave the biggest pellet volume (30.50 $mm^{3)}$ and weight (91.05 mg), but a quantity of 500 g seeds/ run gave maximum sphericity percentage (78.245) and true density (3.374 mg/$mm^{3)}$. It could be concluded that amount of 250 g seeds/ run showed promising characteristics of physical properties suitable for the aim of this study.

Effect of ratio of pelleting material: Seed quantity on some physical properties:

Data presented in Table (3) show pellet dimensions were affected significantly by ratio of pelleting material weight used in pelleting process to seed weight. The ratios used were 5:1, 10:1 and 20:1, whereas, maximum dimensions were obtained when ratio of 20:1 was applied giving values of 4.58, 3.93 and 3.31 mm for major, intermediate and minor dimensions respectively, but ratios of 5:1 or 10:1 produced smaller pellets. Such finding may be due to increasing pelleting material in the pan during process which allow enough pelleting material to reach seed and producing bigger pellet size. Accordingly, geometric diameter and volume showed the maximum values in seeds pelleted at a ratio of 20:1 their values were 3.88 mm and 38.86 mm^3, respectively. However, sphericity percentage of pellets produced at a ratio 5: 1 showed less value meaning that, when pelleting material used was five fold the amount of seed , the produced pellets were less round. Pellet produced with a pelleting material 20 fold seed weight formed the heaviest pellet (109.08 mg), such pellet showed maximum true density (3.235mg/ mm^3).

Effect of adhesive concentration on some physical properties of sesame pelleted seeds

Data presented in (Table 4) demonstrate the effect of adhesive concentration on pelleting process, whereas, significant effects of adhesive concentration were found in all studied characters. Increasing adhesive material (Arabic gum) up to 10 and 20% did not affect significantly producing pellets with more favorable characteristics. However, pellets produced by using solution of 5 and 10% adhesive concentration gave biggest pellet volume of 32.93 and 31.79 mm^3 respectively. On the other hand, more adhesive concentration (20%) produced pellets with smaller volume 22.64 mm^3. Significant differences were found in sphericity percentage, pellet weight and true density in the three different adhesive concentration used in producing pellets whereas, applying 5% adhesive solution produced pellet with maximum values of 81.53%, 107.61mg and 3.462 mg/ mm^3, respectively. Therefore, it is concluded that physical properties of pellets affected by concentration of adhesive solution.

Table 3. Effect of ratio of pelleting material to seed quantity on some physical properties of sesame pelleted seeds.

Pelleting material : seed quantity	Seed axial dimensions, mm			Geometric diameter mm	Volume mm^3	Sphericity %	Weight mg	True density mg/ mm^3
	Major	Inter-mediate	Minor					
Untreated seed	3.50	2.03	0.90	1.85	7.52	52.90	0.032	0.044
5:1	4.20	2.97	2.50	3.18	20.51	72.87	40.77	2.434
10:1	4.66	3.71	3.02	3.73	35.02	80.61	53.44	1.828
20:1	4.58	3.93	3.31	3.88	38.86	85.17	109.08	3.235
LSD at 50%	N.S	0.86	0.79	0.87	19.96	5.72	17.42	1.59

Table 4. Effect of adhesive solution concentration on some physical properties of sesame pelleted seeds.

Adhesive solution conc.	Seed axial dimensions, mm			Geometric diameter mm	Volume mm^3	Sphericity %	Weight mg	True density mg/ mm^3
	Major	Inter-mediate	Minor					
Untreated seed	3.50	2.03	0.90	1.85	7.52	52.90	0.032	0.044
5 %.	4.59	3.67	3.14	3.73	32.93	81.53	107.61	3.462
10 %.	4.54	3.60	2.81	3.56	31.79	78.33	82.02	2.894
20 %.	4.25	3.07	2.52	3.18	22.64	71.86	54.78	3.076
LSD at 50%	0.59	0.83	0.91	0.81	16.36	7.87	17.68	1.74

Effect of quantity of adhesive solution on some physical properties of sesame pelleted seeds

Quantity of adhesive solutions was considered as one of the most important factor affecting the pelleting process. These different quantities of solution were 50, 125 and 150 mm^3/ 500 g pelleting material. Results in Table (5) indicate that applying amount of 50 mm^3/ 500 g pelleting material gave considerable pellet dimensions of 4.51, 3.41 and 2.50 mm for the three dimensions major, intermediate and minor diameters, respectively. While pellets produced by applying both 125 and 150 mm^3/ 500g pelleting material gave close dimensions to that of the smaller amount used. Therefore, it could be concluded that increasing amount of adhesive solution had no significant effect on increasing dimension, geometric diameter and pellet volume. Meanwhile, sphericity percentage reached the maximum (74.19%) when 50mm^3 was used to produce sesame pellets. Therefore such amount of adhesive solution produced more round pellets. Moreover, applying amount of adhesive solution of 50 mm^3/ 500 g pelleting material produced heavier pellets (119.57 mg), the true density of such pellets was 5.362 mg/mm^3. Therefore, applying amount of 50 mm^3/ 500 g pelleting material produced pellets with pronounced characteristics.

Table 5. Effect of volume of adhesive solution to pelleting material (filler) on some physical properties of sesame pelleted seeds.

Volume of adhesive solution/ filler weight	Seed axial dimensions, mm			Geometric diameter mm	Volume mm³	Sphericity %	Weight mg	True density mg/ mm³
	Major	Inter-mediate	Minor					
Untreated seed	3.50	2.03	0.90	1.85	7.52	52.90	0.032	0.044
50 mm³/500g	4.51	3.41	2.50	3.35	29.79	74.19	119.57	5.362
125 mm³/500g	4.35	3.06	2.55	3.13	23.29	72.88	65.85	4.126
150 mm³/500g	4.47	3.34	2.72	3.11	26.99	76.33	44.17	1.842
LSD at 50%	N.S	0.93	0.91	0.90	N.S	8.38	N.S	3.42

Effect of pelleting material composition on some physical properties of sesame pelleted seeds

Data presented in Table (6) show the ratio of both Pentonite and lime used in pelleting material, whereas, maximum pellet dimension varied according to the ratio of elements of pelleting material. The maximum major dimension was produced when a ratio of (25% pentonite + 75% lime) was used giving a value of 4.74 mm, maximum intermediate dimension (3.93 mm) was achieved when a ratio of (100% pentonite + 0 lime) was used, and maximum minor dimension of pellets (3.02 mm) was produced when a ratio of (75% pentonite + 25% lime) was used, which also produced maximum geometric diameter (3.71 mm) and maximum volume (34.95 mm³). Moreover, such treatment produced more round pellet since sphericity percentage recorded a maximum value of 79.25%, the weight of such pellet reached 119.84 mg., true density gave a value of 4.063 mg/mm³. Although the three dimension varied between treatments, pellet produced by using material of (75% pentonite + 25% lime) gave pronouncing characteristics of volume and sphericity percentage.

Table 6. Effect of Pentonite: Lime ratio used in pelleting material on some physical properties of sesame pelleted seeds.

Pentonite: lime ratio	Seed axial dimensions, mm			Geometric diameter mm	Volume mm³	Sphericity %	Weight mg	True density mg/ mm³
	Major	Inter-mediate	Minor					
Untreated seed	3.50	2.03	0.90	1.85	7.52	52.90	0.032	0.044
100% Pentonite	4.28	3.93	2.43	3.16	21.04	72.86	56.77	3.858
25% pent: 75% lime	4.74	3.62	2.97	3.68	34.30	77.90	87.29	3.093
50% pent: 50% lime	4.64	3.41	2.84	3.54	30.09	76.16	114.69	4.801
75% pent.: 25% lime	4.69	3.68	3.02	3.71	34.95	79.25	119.84	4.063
100% lime	4.41	3.47	2.86	3.51	29.47	79.40	107.28	4.533
LSD at 5%	0.83	0.96	0.92	0.86	N.S	7.87	11.16	3.089

Effect of pelleting parameters on some mechanical properties of sesame pelleted seeds:

Since angle of repose of seeds is depended on the pellet shape, size and dimensions, such character must be considered in designing machines that handle and planting the pelleted seeds. However, data obtained show no significant differences due to all treatments under investigation (Tables 7-12).

Also, coefficient of friction was considered in the present investigation since such factor is related to mechanical motion of pellets on metal surface especially planters revealing a pellet character responsible for facilitating pellet flow in planters. Rotational pan speed of 45 rpm showed less coefficient of friction (0.713) of produced pellets (Table 7) when compared to other pelleted seeds. Using 250 g seed/ run showed less coefficient friction (0.726) compared to the other seed quantity exposed to the pelleting process (Table 8). Meanwhile, applying fillers at ratio of 5 times the seed in pelleting pan, using 10 % adhesive concentration, using 125 mm^3 adhesive solution / 500g pelleting material and 100% Pentonite gave coefficient of friction values of 0.675, 0.589, 0.694 and 0.694, respectively (Tables 9-12).

Figures 2, 3 and 4 show the effect of pelleting parameters on the max. contact stress, cutting strength and the pellet hardness . It is clear that max. contact stress and cutting strength decreased with increasing the geometric diameter of the pelleted seeds for the parameters that were used. This could be due to the decrease in the unit density. However, pellet hardness increased with increasing the geometric diameter of the pelleted seeds for the parameters that were used. This may be due to the effect of adhesive solution and the applied heat during process.

Effect of pelleting parameters on some biological properties of sesame seeds

Data presented in Tables (7-12) show response of some biological properties (Germination and vigor percentages and germination rate) to the selected investigated parameters affecting pelleting process of sesame seed. It was previously reported that pelleting increased germination rate, more uniform emergence, germination under a boarder range of environments, and improved seedling vigor and growth (Copeland and McDonald, 1995). Pelleting sesame seeds was found to reduce germination percentage and vigor percentage at all levels of studied parameters when pelleted seed compared to untreated seeds. Pelleting process required to hydrate seeds with adhesive solution and re-drying the pellets which contained seed again. Also, using some filler to form a pellet and cementing additives (Arabic gum) may hinders the germination causing a slight reduction of percentage. However, surrounding the seed with a pellet to improve precision planting and facilitate the free flow of these seeds in planters may overcome the reduction occurred in germination percentage. Because pelleting material is wet during process so that inadvertent seed hydration occurs, this leads to increase respiration and possibly reduced seed quality. In other instance, if the pelleting material is too hard after drying, it may be difficult for radical emergence through the pellet material. Therefore, such technical problems must be monitored during pelleting process so that seed quality is maintained and germination is not hindered. Maximum germination percentages of pelleted seeds were obtained when 60 rpm drum speed, 100 g seed / run, ratio of fillers was 5 times the seed weight (5:1), 20 % adhesive concentration and ratio of 100% Pentonite : 0% lime filling material were used. Maximum Vigor percentage of pelleted seeds recorded when 45 rpm drum speed, 100 g seed/ run, (5:1) ratio of fillers weight: seed weight, 5% adhesive concentration, and ratio of 100% Pentonite: 0% lime filling material were applied. Compared to raw seed (untreated seed), pelleted seeds were superior in germination rate, whereas, maximum values were obtained as speed of 60 rpm for the drum, 100 g seed/ run, ratio of fillers was 10 times the seed weight (10:1), 5 % adhesive concentration and ratio of 100% Pentonite: 0% lime filling material were used.

Table 7. Effect of rotational speed of pelleting pan on some mechanical and biological properties of sesame pelleted seeds.

Pan rotational speed (rpm)	Angle of repose deg.	Coefficient friction	Germination percentage	Vigor percentage	Germination rate
Untreated seed	17.00	0.675	88.50	80.25	0.73
15	18.00	1.235	68.25	60.00	0.89
30	16.25	1.009	65.75	57.00	0.89
45	14.75	0.713	72.50	65.25	0.92
60	14.25	1.280	73.50	63.50	0.93
LSD at 50%	N.S	0.127	10.86	4.48	0.06

Table 8. Effect of seed amount per run on some mechanical and biological properties of sesame pelleted seeds.

Seed quantity (g)/ run	Angle of repose deg.	Coefficient friction	Germination percentage	Vigor percentage	Germination rate
Untreated seed	17.00	0.675	88.50	80.25	0.73
100 g.	14.00	0.754	71.50	65.50	0.93
250 g.	16.00	0.727	70.25	61.00	0.88
500 g.	17.25	1.018	70.25	62.00	0.76
LSD at 50%	N.S	0.103	6.09	5.22	0.08

Table 9. Effect of ratio of pelleting material to seed quantity on some mechanical and biological properties of sesame pelleted seeds.

Pelleting material : seed quantity	Angle of repose deg.	Coefficient friction	Germination percentage	Vigor percentage	Germination rate
Untreated seed	17.00	0.675	88.50	80.25	0.73
5:1	14.25	0.675	72.25	60.50	0.90
10:1	16.00	1.268	65.00	59.75	0.91
20:1	17.25	0.974	65.00	60.00	0.85
LSD at 50%	N.S	0.095	7.93	2.54	0.06

Table 10. Effect of adhesive solution concentration on some mechanical and biological properties of sesame pelleted seeds.

Adhesive solution concentration	Angle of repose deg.	Coefficient friction	Germination percentage	Vigor percentage	Germination rate
Untreated seed	17.00	0.675	88.50	80.25	0.73
5 %	15.00	0.747	67.25	61.75	0.91
10 %	15.50	0.589	63.00	59.50	0.82
20 %	13.75	0.687	71.25	59.75	0.85
LSD at 50%	N.S	0.072	8.69	3.25	0.07

Table 11. Effect of volume of adhesive solution to seed quantity on some mechanical and biological properties of sesame pelleted seeds.

Volume of adhesive solution : seed weight	Angle of repose deg.	Coefficient friction	Germination percentage	Vigor percentage	Germination rate
Untreated seed	17.00	0.675	88.50	80.25	0.73
50 mm^3/ 500 g	13.50	1.235	71.75	60.25	0.90
125 mm^3/ 500 g	14.00	0.694	71.50	59.75	0.87
150 mm^3/ 500 g	14.50	1.224	70.25	59.50	0.82
LSD at 50%	N.S	0.252	4.86	3.37	0.08

Table 12. Effect of Pentonite: lime ratio used in pelleting material on some mechanical and biological properties of sesame pelleted seeds.

Pentonite : lime ratio	Angle of repose deg.	Coefficient friction	Germination percentage	Vigor percentage	Germination rate
Untreated seed	17.00	0.675	88.50	80.25	0.73
100% Pentonite	13.75	0.694	71.25	59.25	0.89
25% pent: 75% lime	19.25	0.949	64.75	58.00	0.78
50% pent: 50% lime	18.25	1.082	66.00	57.25	0.84
75% pent.: 25% lime	17.00	1.192	55.50	51.75	0.77
100% lime	16.00	1.054	66.50	56.25	0.83
LSD at 50%	N.S	0.106	14.09	6.64	0.07

Effect of pelleting process on seed quality

Since the biological parameters are considered as the major target for maintain high seed quality during and after pelleting process, data were subjected to backward multiple regression analysis for physical and mechanical parameters versus biological parameters under investigation (Table 13). It was found that geometric diameter, pellet weight, angle of repose and coefficient friction show no significant relation with germination %, whereas, all physical and mechanical parameters contribute with a percentage of 69% on germination %. As the four non-significant parameters previously mentioned eliminated, they had an effect with 2 % only, while parameters of true density, sphericity, volume, intermediate diameter major diameter and minor diameter showed a contribution percentages of 4%, 6%, 9%, 3%, 7% and 38%, respectively, meaning that parameters of pellet axial dimensions and pellet volume and sphericity are the major variables had a remarkable relation with germination. Results of backward multiple regressions for physical and mechanical variables with vigor % showed similar attitude. Whereas, geometric diameter, angle of repose and coefficient friction showed no significant relation on vigor %. The most effective variables related to vigor % were true density, pellet weight, sphericity %, pellet volume, intermediate diameters minor diameter and major diameter with percentages of 2%, 2%, 3%, 5%, 4%, 24% and 41%, respectively.

Data in Table (13) show that intermediate diameter, geometric diameter, pellet weight, true density, angle of repose and coefficient of friction had no significant relation with germination rate. As these variables eliminated, it was found that their contribution a percentage of 3% only. On the other hand, angle of repose, minor diameter, pellet volume and major diameter show the greatest related variables with germination rate with a percentage of 2%, 19%, 3% and 14% respectively. It could be concluded that pellet seed axial dimensions, pellet volume and pellet sphericity % are the variables significantly related to biological parameters.

Multiple regression analysis was performed for relation of some physical and mechanical variables with biological properties (Germination %, Vigor % and germination rate) for the studied parameters affecting pelleting process (Table 14), whereas, results reveal that germination percentages were related with intermediate diameter minor diameter and geometric diameter as affected by rotational pan seed (rpm) parameters, major, intermediate and minor diameter as affected by seed quantity/ run parameters, major, minor, geometric diameters and pellet volume as affected by adhesive concentration parameters, major, intermediate, minor, diameters and pellet volume as affected by quantity of adhesive solution and ratio of pelleting material : seeds parameters and minor diameter as affected by ratio of pent.: lime parameters. It could be concluded that pellet dimensions and volume as physical variables were related and affect germination percentages when each investigated parameter was considered. Similar results were observed when multiple regression analysis was performed for relation of some physical and mechanical variables with vigor %, therefore, the most physical properties related to vigor % were pellet dimensions and volume.

Germination rate was related to pellet dimensions, pellet geometric diameter and sphericity % as affected by rotational pan seed parameters. Seed quantity / run and adhesive concentration parameters affect the relation between major diameter and minor diameter with germination rate.

F 2

3

4

Meanwhile, quantities of adhesive solution affect the relation between major diameter and sphericity % characters. Ratio of pelleting material: seeds parameters show significant effect on the relation between germination rate and major diameter, sphericity %, true density and angle of repose variables. Ratio of Pentonite: Lime in pelleting material show significant effect on the relation between germination rate and minor diameter.

Importance and significance of all investigation variables on the relation between physical and mechanical properties with biological investigated properties under each studied factor during eliminating each variable were presented in Table (14).

Table 13. Backward multiple regression analysis (overall studied factors) for germination and vigor percentages and germination rate

Step.	I. Germination percentage											
	Const.	$\pm bv_1$	$\pm bv_2$	$\pm bv_3$	$\pm bv_4$	$\pm bv_5$	$\pm bv_6$	$\pm bv_7$	$\pm bv_8$	$\pm bv_9$	$\pm bv_{10}$	R^2(%)
Step 0	193.1	-11.3*	-1.3*	8.6*	-1.2ns	0.60*	-1.2*	5.4ns	-1.5*	-0.4ns	-0.1ns	69
1	196.5	-12.1*	-2.1*	9.3*	-1.1ns	0.6*	-1.3*	6.5ns	-1.5*	-0.4ns	E	69
2	198.2	-12.4*	-2.1*	9.4*	-0.2ns	0.6*	-1.3*	E	-1.3*	-0.4*	E	68
3	198.3	-12.4*	-2.2*	9.3*	E	0.6*	-1.3*	E	-1.3*	-0.4*	E	68
4	185.3	-11.1*	-3.8*	8.1*	E	0.7*	-1.2*	E	-1.3*	E	E	67
5	201.9	-13.4*	-0.3*	8.4*	E	0.8*	-1.5*	E	E	E	E	63
6	145.3	-5.7*	-21.0*	-10.1*	E	1.7*	E	E	E	E	E	57
7	61.3	4.7*	12.2*	-19.5*	E	E	E	E	E	E	E	48
8	59.7	10.3*	E	-13.1*	E	E	E	E	E	E	E	45
9	89.1	E	E	-7.0*	E	E	E	E	E	E	E	38
	II. Vigour percentage											
Step 0	138.3	-8.9*	-1.4*	-1.0*	2.8ns	0.4*	-0.6*	-7.1*	-1.0*	0.2ns	-0.1ns	83
1	136.8	-8.1*	-0.1*	0.02*	E	0.4*	-0.6*	-7.4*	-0.9*	0.2ns	-0.1ns	82
2	144.3	-8.9*	0.7*	0.7*	E	0.4*	-0.7*	-8.7*	-0.9*	E	-0.1ns	82
3	147.5	-9.4*	0.3*	2.0*	E	0.4*	-0.8*	-7.5*	-0.9*	E	E	81
4	158.5	-11.2*	1.9*	2.2*	E	0.5*	-1.0*	-20.5*	E	E	E	79
5	159.9	-11.1*	3.2*	2.1*	E	0.4*	-1.0*	E	E	E	E	77
6	121.4	-5.9*	-10.8*	-10.5*	E	1.1*	E	E	E	E	E	74
7	67.7	0.8*	10.5*	-16.5*	E	E	E	E	E	E	E	69
8	66.3	5.6*	E	-11.0*	E	E	E	E	E	E	E	65
9	104.1	-9.4*	E	E	E	E	E	E	E	E	E	41
	Germination rate											
Step 0	0.30	0.11*	-0.14ns	0.01*	0.04ns	-0.002ns	0.01*	-0.03ns	8.3ns	-0.003ns	2.82ns	41
1	0.29	0.11*	-0.14ns	0.01*	0.04ns	-0.002*	0.01*	E	1.73ns	-0.003ns	3.02ns	41
2	0.29	0.11*	-0.14ns	0.01*	0.04ns	-0.002*	0.01*	E	E	-0.003ns	3.02ns	41
3	0.27	0.11*	-0.14ns	0.003*	0.04ns	-0.002*	0.01*	E	E	-0.003ns	E	41
4	0.23	0.11*	E	0.014*	0.02ns	-0.007*	0.004ns	E	E	-0.003ns	E	39
5	0.22	0.11*	E	0.02*	E	-0.007*	0.004ns	E	E	-0.003ns	E	39
6	0.49	0.09*	E	0.09*	E	-0.007*	E	E	E	-0.004*	E	38
7	0.40	0.09*	E	0.10*	E	-0.008*	E	E	E	E	E	36
8	0.40	0.12*	E	E	E	-0.003ns	E	E	E	E	E	17
9	0.62	0.05*	E	E	E	E	E	E	E	E	E	14

E: Eliminated variable b: Slop

v_1-v_{10} : Variable arranged respectively as follow (major dia, intermediate dia., minor dia., geometric dia, volume, sphericity, weigh, true density, angle of repose and coefficient friction

***: Significant values, ns : Non-significant values**

Table 14. Multiple regression analysis of physical and mechanical variables for biological properties of sesame pelleted seeds.

step	constant	b*V1	b*V2	b*V3	b*V4	b*V5	b*V6	b*V7	b*V8	b*V9	b*V10	R^2 %
					A. Rotational speed of pelleting pan							
					1. Germination %							
0	25.17	116.72	104.34 **	171.58 *	-359.67 **	-0.98	-0.56	210.73	1.90	-0.76	0.11	87.7
1	23.42	114.43	104.41 **	167.91 *	-348.63 **	-1.28	-0.64	260.95		-0.78	0.09	87.6
2	27.08	112.66	102.20 **	165.25 *	-345.68 **	-1.07	-0.53	235.98 *		-0.79		87.3
3	-1.14	123.57	100.29 **	169.16 **	-367.24 **	-0.78		245.23 *		-0.79		87.2
4	32.64	107.67	80.83 **	151.09 **	-328.83 **			213.37 **		-0.75		86.9
5	49.09		-13.15 *	-47.71 **	53.76			241.83		0.29		56.7
6	55.10		-12.90 *	-46.22 **	51.89			243.72				56.0
7	70.12		17.20 *	-23.41 *				189.00				50.0
8	62.94		18.31 *	-19.31 *								41.8
9	86.87			-5.84 *								28.2
					2. Vigor %							
0	-32.53	81.86 **	30.54 **	78.36 *	-211.43 **	0.65	1.51	215.90	-4.01	0.34	-0.17	92.0
1	-28.82	86.70 **	30.39 **	86.12 *	-234.79 **	1.28	1.67	109.66		0.39	-0.13	91.7
2	58.33	53.09 **	36.71 **	74.43 *	-168.22 **	0.35		85.24		0.38	-0.11	90.5
3	46.65	58.04 **	38.97 **	78.71 *	-177.34 **	0.17		118.51		0.39		89.8
4	43.72	70.58 **	51.47 **	100.79 *	-219.63 **	-0.01		125.61				88.4
5	44.32	70.31 **	51.14 **	100.50 *	-219.00 **			125.05 *				88.4
6	42.64	72.80 **	60.86 **	112.64 *	-239.61 **							83.9
7	54.85	14.59 **	3.15 **	-19.88								66.2
8	59.30	15.05 **	-18.92 **									58.1
9	89.02		-8.03 **									44.8
					3. Germination rate							
0	-0.10	-0.06 **	-1.08 *	-0.89 *	0.93 **	0.05	0.03 *	-5.43	0.19	0.00	0.00 *	90.3
1	-0.12	-0.01 **	-1.01 *	-0.79 *	0.77 **	0.05	0.03 *	-5.06	0.18		0.00 *	89.8
2	-0.11	-0.17 **	-0.52	-0.79	1.39 **		0.01	-1.63	0.07		0.00	82.2
3	-0.21	-0.29 **	-0.73	-1.08	1.95 **		0.01	0.00			0.00	80.5
4	-0.21	-0.29 **	-0.73	-1.08	1.95 **		0.01				0.00	80.5
5	-0.50	-0.18 **	-0.67	-1.04	1.72 **		0.02					76.9
6	0.93	-0.77 **	-0.91	-1.46	3.05 **							72.6
7	0.77	-0.01 *	-0.16		0.21							40.0
8	0.79	-0.04 *			0.09							36.0
9	0.57	0.07 *										23.8
					B. Seed quantity / run							
					1. Germination %							
0	169.86	-22.20 **	-32.85 **	-34.32 **	54.44	1.11	-0.02	94.23	-2.36	-0.42	-0.21	89.1
1	170.33	-22.45 **	-33.44 *	-34.55 *	54.84	1.13		92.88	-2.35	-0.42	-0.21	89.1
2	172.89	-23.89 **	-29.92 *	-33.94 **	50.46	1.37			-0.58	-0.19	-0.30	88.7
3	165.99	-23.28 **	-29.61 **	-37.81 **	53.76	1.37				-0.09	-0.31	88.6
4	162.92	-22.67 **	-29.12 **	-37.63 **	53.23	1.34					-0.32	88.5
5	178.33	-28.52 **	-42.46 **	-39.72 **	64.44	1.66						86.3
6	117.45	-4.23 **	-4.09 *	-12.93 **		0.69						77.8
7	75.13	2.01 **	11.24 *	-19.10 **								76.6
8	78.46	5.28 **		-11.56 **								72.5
9	114.87	-9.97 **										40.2
					2. Vigor %							
0	55.53	10.85 **	19.24 **	-0.12 **	-12.96	-0.86	-0.64 *	131.21	-2.78	0.72	-0.01	96.6
1	55.70	10.84 **	19.14 **	-0.09 **	-12.85	-0.86	-0.65 *	133.05	-2.81 *	0.71		96.6
2	65.80	5.57 **	7.69 **	-6.79 **		-0.49	-0.46 *	126.90	-2.75 *	0.78		96.4
3	81.67	-0.58 **	2.75 **	-7.49 **		0.14	-0.31 *		-0.65	0.99 *		95.2
4	75.53	0.57 **	6.03 **	-8.28 **			-0.37 *		-0.52	1.00 *		95.2
5	74.15	1.26 **	7.04 **	-9.08 **			-0.43 **			1.05 **		95.0
6	42.64	4.65 **	6.57 **	-15.75 **						1.26 **		93.1
7	65.57	1.34 **	12.18 **	-18.34 **								84.6
8	69.18	4.89 **		-10.17 **								77.8
9	101.22	-8.53 **										42.1

Table 14 Cont.

step	constant	b*V1	b*V2	b*V3	b*V4	b*V5	b*V6	b*V7	b*V8	b*V9	b*V10	R^2 %
3. Germination rate												
0	1.36	-0.11 *	-0.47	0.15 *	0.15	0.01	0.00	-1.29	0.02	-0.01	0.00	82.0
1	1.29	-0.13 *	-0.50	0.11 *	0.17	0.02	0.01	-1.95	0.03		0.00	81.3
2	0.67	0.06 *	-0.12	0.19 *	-0.06		0.00	-1.15	0.03		0.00	78.7
3	0.66	0.06 **	-0.15	0.16 **			0.00	-0.99	0.02		0.00	78.6
4	0.60	0.04 **		0.09			0.00	-2.05	0.05 *		0.00	75.9
5	0.59	0.04 **		0.08			0.00	-2.02	0.05 **			75.4
6	0.51	0.05 **		0.06 *				-2.02 **	0.04			75.1
7	0.52	0.06 **		0.00					0.02			56.4
8	0.71	0.00 *		0.05								47.9
9	0.54	0.07 *										36.2
C. Adhesive concentration												
1. Germination %												
0	238.77	-26.35 *	-87.83	-15.42	63.45	2.94 *	-0.03	49.83	-3.86	0.35	-0.28	89.1
1	218.70	-22.23 **	-76.65	-13.21	49.08 *	2.78 **	0.13	23.89	-3.80		-0.11	88.9
2	210.63	-21.67 **	-73.63	-13.23 *	45.21 *	2.82 **	0.19	0.40	-3.43			88.9
3	210.62	-21.68 **	-73.61	-13.23 *	45.19 *	2.82 **	0.19		-3.43			88.9
4	252.86	-16.58 **		26.40 *	-27.84	1.53 **	-1.71 *		-0.46			85.4
5	262.51	-16.69 **		28.35 *	-30.12	1.64 **	-1.86 *					85.3
6	286.46	-29.42 **		17.74 *		1.39 **	-2.31 **					84.0
7	219.67	-18.87 **				1.54 **	-1.46 **					79.9
8	97.68	18.11 **					-1.43 **					62.1
9	119.40	-11.12 *										31.3
2. Vigor %												
0	68.88	1.62 **	-3.14	1.15 *	-23.63 **	0.30	0.79	114.71	-5.03 *	-0.18	0.41	95.6
1	67.32	2.15 **		2.32 *	-27.13	0.26 **	0.76	109.35	-4.90 **	-0.21	0.43	95.5
2	80.04	0.20 **		4.05 *	-25.45	0.28 **	0.54	115.36	-4.55 **		0.37	95.4
3	51.10	0.15 **		-1.49 *	-28.23	0.67 **	1.04		-3.29 *		0.65 *	94.6
4	116.41	-9.54 **		3.84 *	-15.54	0.70 **			-2.27 *		0.49	92.3
5	114.42	-14.87 **		-3.74 *		0.49 **			-2.68 **		0.50	91.7
6	132.52	-15.67 **		-0.76 *		0.32 **			-2.97 **			88.9
7	134.44	-16.37 **				0.30 **			-3.04 **			88.9
8	110.24	-8.82 **							-3.26 **			88.1
9	115.42	-11.88 **										53.6
3. Germination rate												
0	0.94	0.13 **	-0.80	0.09 *	0.38	0.01	0.00	2.39	-0.01	0.01	0.00	88.8
1	0.87	0.19 **	-0.50	0.21 *	0.14		-0.01	2.65	-0.01	0.01	0.00	87.0
2	0.78	0.22 **	-0.41	0.25 **			-0.01	2.38	0.00	0.01	0.00	86.9
3	0.56	0.22 **	-0.38	0.20 **			0.00	1.99	0.00	0.01		86.6
4	0.59	0.21 **	-0.37	0.21 **			0.00	1.93		0.01		86.6
5	1.48	-0.12 *		0.17			-0.01	1.78		0.00		59.7
6	0.94	-0.08 **		0.06				0.92		0.00		56.5
7	0.95	-0.08 **		0.06				0.87				56.2
8	1.01	-0.10 **		0.11								50.7
9	0.46	0.09 **										39.3
D. Quantity of adhesive												
1. Germination %												
0	187.15	-16.60 **	-26.20 *	-2.33 **	11.90	1.47 *	-0.21	-3.26	-1.33	-0.36	-0.03	93.2
1	198.98	-18.66 **	-27.45 *	-0.54 **	13.13	1.54 **	-0.35	-3.10	-1.33	-0.39		93.1
2	241.02	-22.97 **	-17.31 *	10.78 **		1.71 **	-1.06	-2.49	-0.64	-0.24		92.4
3	227.45	-21.24 **	-20.54 **	8.70 **		1.81 **	-0.84 *	-1.29	-0.66			92.2
4	224.53	-20.83 **	-19.41 **	8.38 **		1.75 **	-0.85 *		-0.70			92.2
5	265.18	-26.42 **	-9.64 **	16.86 **		1.56 **	-1.75 *					89.6
6	212.48	-15.94 **	-45.41 *	0.34 **		2.91 **						84.0
7	109.79	-4.66 **		-15.34 **		0.85						73.7
8	54.73	12.55 **		-14.77 **								66.2
9	89.64	**		-6.52 **								53.1

Table 14. Cont.

step	constant	b*V1	b*V2	b*V3	b*V4	b*V5	b*V6	b*V7	b*V8	b*V9	b*V10	R^2 %
						2. Vigor %						
0	50.31	-1.11 **	-42.36 **	-30.84 **	24.21	1.15 **	1.90 *	-13.71 *	-2.32 *	-0.27	-0.05	98.3
1	68.43	-4.25 **	-44.28 **	-28.10 **	26.10 *	1.25 **	1.69 *	-13.46 **	-2.31 *	-0.31		98.1
2	63.62	-3.37 **	-45.40 **	-27.60 **	22.75 *	1.41 **	1.75 *	-11.93 **	-2.16 **			97.9
3	151.27	-12.74 **	-24.29 **	-5.70 **		1.59 *	0.30 *	-12.18 **	-0.94 *			96.1
4	207.43	-20.53 **	-18.98 **	4.72 **		1.66 *	-0.65	-17.92 *				93.3
5	190.68	-17.19 **	-32.94 **	-0.96 **		2.19 *		-19.59 **				92.8
6	73.89	1.31 **	6.32 *	-14.56 **				-16.93 *				85.6
7	64.34	3.89 **	7.08	-16.93 **								78.0
8	59.43	8.66 **		-14.27 **								77.0
9	107.63	-10.15 **										50.3
						3. Germination rate						
0	0.54	0.16 *	-0.53	-0.03	-0.17	0.03	0.02 *	-0.01	0.03	0.00	0.00	84.0
1	0.53	0.17 *	-0.53	-0.03	-0.17	0.03	0.02 *		0.03	0.00	0.00	84.0
2	0.58	0.16 *	-0.51	-0.03	-0.13	0.02	0.01 **		0.02		0.00	83.6
3	0.74	0.13 **	-0.53	-0.01	-0.12	0.03	0.01 **		0.02			83.3
4	1.44	0.03 **		0.22	-0.30	0.01	-0.01 *		0.03 *			78.9
5	0.33	0.12 *		-0.03		0.00	0.00 *		0.02 *			73.3
6	0.39	0.11 **		-0.02			0.00 *		0.02 **			73.3
7	0.48	0.10 **					0.00 *		0.02 **			73.2
8	0.47	0.07 **							0.02 **			72.0
9	0.78	**							0.02 **			38.8
						E. Ratio of plleting material: seeds						
						1. Germination %						
0	226.46	-24.77 **	-58.79 **	-6.86 **	57.02	1.28 **	-0.56	88.34	-4.63	-0.15	-0.26	97.3
1	135.17	-2.49 **	-45.35 *	-9.55 *		1.95 **	1.01	118.17	-3.74	-0.23	-0.06	91.5
2	137.50	-2.84 **	-43.51 *	-8.26 **		1.89 **	0.87	112.31	-3.63	-0.21		91.4
3	176.46	-9.39 **	-33.35 *	2.84 **		1.64 **		52.66	-2.80	-0.15		91.2
4	190.00	-10.16 **	-42.72 *	5.18 *		2.11 *		21.69	-2.35			90.8
5	193.56	-10.23 **	-45.06 **	5.24 **		2.27 **			-1.91			90.8
6	197.96	-9.12 **	-48.42 **	-0.53 **		2.73 **						89.2
7	120.13	-7.74 **		-14.60 **		0.95 *						78.6
8	80.60	3.76 **		-9.31 **								64.1
9	107.05	-7.64 *										38.4
						2. Vigor %						
0	290.84	-47.58 **	53.57 *	36.03 **	34.70	-2.02	-4.40	-169.70 *	-1.56	0.13	-0.11	97.7
1	288.44	-46.64 **	57.54 **	37.98 **	30.80	-2.08	-4.53	-177.34 **	-1.32	0.15		97.4
2	258.54	-42.59 **	61.05 **	31.35 **	28.96	-2.32	-4.11 *	-126.69 **	-1.99			97.2
3	219.84	-32.09 **	62.95 **	30.45 **		-1.74	-3.20	-122.66 *	-1.43			95.3
4	240.46	-34.57 **	64.79 **	33.32 **		-1.57	-3.58	-173.81 **				95.0
5	117.91	-8.46 **	-3.23 *	-11.70 **		1.09		-52.83				87.9
6	111.73	-7.67 **	0.56 *	-15.12 **		0.94						87.0
7	70.87	-5.09 **	21.75 *	-20.36 **								84.4
8	72.89	3.87 **		-9.64 **								71.7
9	100.27	-7.94 **										43.1
						3. Germination rate						
0	2.15	0.18 *	-1.21	0.22	-0.54	0.09	0.01 *	-8.38	0.21**	0.01*	0.00	92.6
1	3.02	-0.03 *	-1.34	0.25		0.08	-0.01 *	-8.67	0.20**	0.01*	-0.01	88.3
2	-1.12	0.55	-1.63	-0.79		0.07	0.07		0.06	0.00	-0.01	62.9
3	-1.12	0.55	-1.63	-0.79		0.07	0.07		0.06		-0.01	62.9
4	-0.40	0.22		-0.29		0.00	0.02		0.04		0.00	38.2
5	0.43	0.11				-0.01	0.00		0.02		0.00	32.8
6	0.21	0.12				-0.01	0.01				0.00	31.1
7	0.74	0.00					0.00				-0.01	22.8
8	0.67	0.05									0.00	15.5
9	0.61	0.05										14.3

Table 14. Cont.

step	constant	b*V1	b*V2	b*V3	b*V4	b*V5	b*V6	b*V7	b*V8	b*V9	b*V10	R^2 %
						F. Ratio of pent.: lime						
						1. Germination %						
0	189.26	-7.27	29.87	-1.41 **	-0.83	-0.19	-1.73	37.53	-1.21	-1.20	-0.58	66.8
1	122.27	0.32	7.36	-21.45 **	-3.03	0.92		1.31	-1.10	-0.96	-0.45	65.5
2	127.24	-1.62	5.24	-22.08 **		0.99		2.53	-1.19	-0.95	-0.44	65.3
3	135.11	-4.72	-4.66	-17.03 **		1.37		-77.85	-0.86	-0.89		63.5
4	128.93	-5.00	2.36	-22.11 **		1.39		-111.61		-1.05		63.0
5	132.74	-5.11		-21.33 **		1.47 *		-109.98		-1.05		63.0
6	111.59	-4.44		-17.70 **		1.18 *		-125.00				58.8
7	104.17	-0.33		-28.52 **		1.43 *						53.5
8	103.15			-28.59 **		1.42 **						53.5
9	73.38					-0.18						4.4
						2. Vigor %						
0	75.97	1.67 **	9.21 *	-17.93 **	-0.75	0.35	-0.12	-94.40	0.47	0.05	0.01	87.9
1	76.22	1.67 **	9.46 **	-17.88 **	-0.75	0.34	-0.13	-93.17	0.46	0.05		87.9
2	77.82	1.50 **	10.18 **	-17.81 **	-0.73	0.32	-0.16	-93.83	0.50			87.9
3	71.35	2.31 **	8.52 **	-20.03 **	-0.97	0.42		-95.33	0.51			87.9
4	72.95	1.70 **	7.92 **	-20.29 **		0.44		-94.75 *	0.49			87.8
5	78.05	1.81 **	4.11 **	-17.78 **		0.45		-74.29 *				87.4
6	55.32	4.09 **	14.07 **	-20.22 **				-86.45				86.7
7	40.31	8.96 **	16.13 **	-28.13 **								81.9
8	34.44	17.36 **		-19.94 **								76.4
9	101.94	-9.48 **										39.2
						3. Germination rate						
0	1.42	0.02	-0.22	0.41 **	-0.04	0.00	-0.01	-0.60	0.01	0.00	0.00	73.7
1	1.46	0.02	-0.18	0.41 **	-0.04	-0.01	-0.01	-0.40	0.01	0.00		73.4
2	1.56	0.02	-0.22	0.43 **	-0.04	0.00	-0.01		0.00	0.00		72.2
3	1.56	0.02	-0.24	0.45 **	-0.03	0.00	-0.01			0.00		71.8
4	1.48	0.03	-0.34	0.40 **	-0.03		-0.01			0.00		71.0
5	1.35	0.04	-0.35	0.39 **	-0.04		-0.01					69.8
6	1.55		-0.34	0.43 **	-0.03		-0.01 *					69.3
7	0.62			0.02 **	-0.06		0.00					14.2
8	0.84			0.08	-0.07							10.7
9	0.76				0.01							2.5

**** = highly significant , * = significant , unmarked values= non significant and blank cells = eliminated value, b = slope**

v_1-v_{10} : Variable arranged respectively as follow (major dia, intermediate dia., minor dia., geometric dia, volume, sphericity, weigh, true density, angle of repose and coefficient friction

SUMMARY AND CONCLUSION

A machine for pelleting small and light sesame seeds was used to enlarge size and change shape to become more heavier and rounder to facilitate handling and planting through a mechanized application. Results of physical, mechanical and biological properties of sesame pelleted seeds as response of pelleting process factors could be summarized as follow:

1-Rotating pan speed of 30 rpm showed the greatest pellet weight, sphericity percentage.

2- Using 250 g seeds/ run showed maximum pellet dimensions, pellet volume and weight.

3- Maximum pellet dimensions and maximum pellet sphericity were obtained when a ratio of pelleting material: seeds was 20:1

4-Adhesive material concentration (5 %) showed a maximum pellet size, volume and weight**.**

5- Quantity of 50 mm^3 adhesive solution per 500 g pelleting material gave maximum pellet volume and weight.

6- Ratio of 75% Pentonite + 25% lime gave maximum pellet dimensions, volume and weight.

7- Germination rate increased when seeds were pelleted .

8- Biological properties were greatly related with pellet dimensions and volume.

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الخصائص الطبيعية والميكانيكية والبيولوجية لبذور السمسم المكبسلة

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محصول السمسم هو أحد اهم المحاصيل لإنتاج الزيوت خاصة في الأراضي المستصلحة حديثاً في مصر. لذا صممت ماكينة لكبسلة بذور السمسم الصغيرة الخفيفة وتم تصنيع الماكينة في حجم معملي لتغيير شكل وحجم بذور السمسم لزيادة حجمها بكبسولة أثقل وأكبر حجماً بغرض تسهيل زراعة السمسم بواسطة آلات تسطير وزراعة البذور. وأختبرت بعض أهم العوامل التي تؤثر على تشغيل الماكينة لدراستها وقد أظهرت النتائج أهمية عوامل الدراسة في التأثير على عملية الكبسلة. أظهرت سرعة دوران وعاء الكبسلة تأثير على الخصائص الطبيعية للكبسولة الناتجة وأعطت سرعة ٣٠ لفة/ دقيقة أكبر كبسولة وأعلى نسبة لإستدارة الكبسولة وأعلى كثافة حقيقية حيث أنها زادت حجم الكبسولة إلى أربعة أضعاف حجم البذور الخام. أظهرت كمية البذور المستخدمة في الكبسلة ٢٥٠ جرام/ دورة تفوقاً بين ثلاثة كميات للبذور تحت الدراسة حيث أعطت أعلى قيمة لأبعاد الكبسولة وحجم الكبسولة ووزنها. تمت دراسة ثلاثة مستويات هى النسبة بين وزن مواد الكبسلة المضافة إلى وزن البذور وهم ١:٥، ١:١٠، ١:٢٠ حيث أعطت المعاملة ١:٢٠ أكبر الكبسولات حجماً ووزناً وأعلى نسبة استدارة للكبسولة (٨٥,١٧%). كما كان لإستخدام أقل تركيز للمادة اللاصقة (٥ جم صمغ عربي/ لتر) نتائج متفوقة لحجم ووزن الكبسولة بالمقارنة بالتركيزات الأعلى للمادة اللاصقة. أيضاً فإن استخدام أقل حجم للمحلول اللآصق (٥٠ مم٣/ ٥٠٠ جرام مادة كبسلة) أعطى أعلى وزن وحجم للكبسولة الناتجة بينما أعطت معاملة استخدام أعلى حجم لمحلول اللصق (١٥٠ مم٣/ ٥٠٠ جرام مادة كبسلة) أعلى نسبة لإستدارة الكبسولة (٧٦,٣٣%). تمت دراسة تأثير تركيب مادة الكبسلة لتحديد أنسب المواد التي تعطي صفات طبيعية جيدة للكبسولة وأظهرت النتائج أن استخدام مادة كبسلة تحتوى على ٧٥% بنتونيت: ٢٥% كربونات كالسيوم أعطى أعلى حجم ووزن للكبسولة الناتجة بينماأعطت معاملة صفر % بنتونيت: ١٠٠% كربونات كالسيوم أعلى نسبة لإستدارة الكبسولة. أنخفضت نسبة الإنبات وقوة الإنبات للبذور المكبسلة بالمقارنة بالبذور الخام غير المعاملة بينما أدت كبسلة البذور إلى ارتفاع سرعة الإنبات بالمقارنة بالبذور غير المعاملة - بناء على ذلك فقد أظهرت النتائج عدم تحسن صفات نسبة وقوة الإنبات بعملية الكبسلة وعلى العكس من ذلك فقد أدت عملية الكبسلة إلى تحسين سرعة الإنبات.أظهرت النتائج أن أبعاد الكبسولة وحجمها ونسبة إستدارتها هي المتغيرات الأساسية التي أظهرت علاقة واضحة مع نسبتي الإنبات والإنبثاق.