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Manufacturing and Evaluating a Small Scale Thermal Unit for Controlling Insect Infested Stored Wheat

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ABSTRACT

The main objective of the present study is to investigate a thermally disinfesting stored wheat . To fulfill the objective of this research work, a small scale unit was designed and manufactured from local material taking into consideration its effectiveness. Preliminary experiments and calibration were conducted to determine the suitable time at the appropriate heating temperature degree. The performance of the manufactured unit was studied as a function of change in the amount of wheat grain (1.0, 2.0 and 3.0 kg) and heating temperature (50, 60 and 70 C°) and evaluated in terms of equipment productivity, germination ratio, mass loss, equipment efficiency, specific energy requirements and production cost. Experimental results revealed that the optimum machine performance is obtained at grains amount of 2 kg and heating temperature 50 C° , which gives 13.3 kg/h equipment productivity, 96% germination ratio, 9% weight loss and 91% equipment efficiency with minimum energy requirements of 0.11 kW.h/kg and production cost of 1.12 LE/kg

Keywords: Thermal treatments, Stored grains losses, Infestation, Specific energy requirement

INTRODUCTION

For the bulk of the world's population, wheat (Triticum aestivum L. em Thell.) is the most important and strategic cereal crop. It is nearly two billion people's most significant staple food (36 percent of the world population). Wheat is responsible for about 55 percent of global carbs and 20 percent of global dietary calories (Breiman and Graur, 1995). It outnumbers all other grain crops in terms of acreage and production (including rice, maize, and others) and it is thus the world's most important cereal grain crop, farmed in a variety of climatic circumstances. Insect pest infestations in the field or during processing and storage are the most serious challenge for grain production and storage. In fact, the attack of stored product insects causes significant quantitative and qualitative losses in cereals during storage. Damage to stored cereals and cereal products can range from 5-10 percent in temperate zones to 20-30 percent in tropical zones (Nakakita, 1998), and has reached 50 percent in wheat infested by (*Sitophilus granarius* (L.) as reported by (Caswell 1981). Weevils may attack seeds in the field during cropping, and juvenile larvae are already infesting dry seeds at harvest time. The growth of juvenile instars and the appearance of a new generation can cause substantial damage to kernels during storage if they are not treated immediately after harvest. In developed countries, damaged seeds with emerging holes do not exceed the quality criteria for human consumption. During boiling, a few kernels with secret post-embryonic stages might spread a foul odor throughout the entire batch of seeds (Dupuis et al., 2006). To improve the quality and availability of cereals for human consumption, pest-related storage losses must typically be reduced by taking control measures promptly after harvest. Chemical pesticides, such as methyl bromide (MeBr) and phosphine, have dominated grain pest treatment for many years. Although effective, they have unintended consequences for other insect species or non-target creatures, and they may harm the environment and human health. Recently, there has been a surge in interest in non-chemical approaches. Thermal treatments at high and low temperatures have been intensively researched as solutions for disinfesting stored grains (Dosland et al., 2006; Dupuis et al., 2006; Loganathan et al., 2011). Temperatures of 25-33°C are ideal for increasing insects. Prolonged exposure to temperatures below 13 °C or above 35 °C is deadly for most stored-product bugs. The more severe the temperature, the faster insects die, with death occurring in minutes at 20 or 55 degrees Celsius (Fields, 1992). Thermal disinfestation treatments are simple to use, leave no chemical residues, It may have antifungal properties. However, the temperature and time combinations necessary to kill insect pests may be equal to or greater than those that affect seed viability, nutritional content, shelf life, or technological qualities (cooking time, texture, hardness, and color after processing, and so on. The grain can be roasted to high enough temperatures to kill insects in two methods. Firstly, hot air (60-120°C) is blasted at high enough rates to lift and mix grain in fluidized beds. Secondly, in little than one minute, the grain's temperature rises to between 56 and 72°C. Small-scale batch (Dermott and Evans, 1978) and continuous flow (Evans et al., 1983; Fleurat-Lessard, 1985) Fluidized-beds capable of treating 150 tons per hour have been constructed and tested. By spraying water on the grain (Evans et al., 1983) or using a fluidized-bed with ambient air, grain may be quickly chilled (Fleurat-Lessard, 1985). If large-scale grain treatment is necessary, fluidized-bed operation costs are comparable to fumigation (Fleurat-Lessard, 1987). Grain and other stored items have also been heated using non-ionizing electromagnetic radiation to temperatures high enough to kill insects. However, these approaches are costly

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and difficult to use on a small scale. So, this research aimed to develop and test a small-scale thermal unit for disinfesting wheat seeds.

MATERIALS AND METHODS

Materials

Experiments were carried out through the spring of 2022 at a private workshop store in Zagazig , Sharkia Governorate, Egypt. The experimental conformed to evaluate a thermal unit for disinfesting stored wheat.

Wheat seeds:

Grain samples were taken from different positions of infested storage systems with the help of a sampler at three different intervals and then mixed completely to get a composite sample. The composite sample was then used for determination of quality parameters

Manufactured Equipment:

Metal sheet with a thickness of 3 mm was used to construct the rotating cylinder drum drier. The dimensions were made with a length of 90 cm and a diameter of 57.5 cm. A feeding inlet was installed around the rotating drum's periphery as shown in Fig 1. The rotary drum is supported by two bearings and features a roller that rotates as a function of a gear and an electrical motor with a reduction ratio. The rotating drum spun slowly at150 rpm. Later, the rotational drum was heated with LPG utilizing four burners at the bottom of the drum. All the previously described pieces were fastened to the equipment frame, which was made of local steel 48 with dimensions of 650×330×300mm.

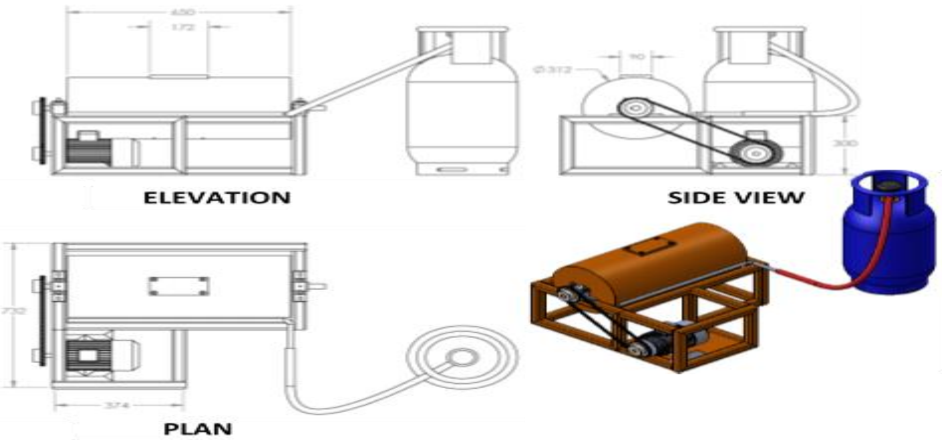

Fig. 1. Detailed drawing of manufactured unit.

Instruments:

0.85 mm diameter of copper – constantan thermocouples, digital vernier and balance, stopwatch, electric oven and petri dishes were used under all treatments.

Methods

Experimental conditions

Preliminary experiments and calibration were conducted at a constant speed of 150 rpm with different mass of wheat seeds (1,2 and 3 kg) and different heating periods to determine the suitable time at the appropriate heating temperature degree.

Experiments were carried out under the following treatments as follow:

- Three different mass of wheat seeds (1,2 and 3 kg)
- Three different temperature degrees (50,60 and 70 C°)

Measurements

The following indicators were taken into consideration for evaluating the performance of manufactured unit as:

Equipment productivity

Equipment productivity was calculated by the following equation:

$$W = m_i \text{ X } \frac{60}{t}$$

Where:

***W*: Capacity of the equipment, kg/h.**
***mi*: Mass of grains from unit, ton.**
***t*: Thermal treatment time, min.**

Germination ratio

A sample of (100 seed) was germinated in A group of Petri dishes of 15 cm diameter and 1 cm height and replicated three times before planting and after thermal treatment to investigate seed germination

Weight losses

The dry weight of 1000 grains is determined from a sample of grain collected at the beginning of the storage season (TGM0) and compared with another measurement after a certain time (TGMt). the weight loss in a sample of grains between period 0 and t is given by:

$$wl = \frac{TGM_0 - TGM_t}{TGM_0} \times 100$$

Where:

wl **= weight losses, %**
TGM_0 = thousand grain mass on a dry basis at the beginning, kg
TGM_t = thousand grain mass on a dry basis after a certain time (t), kg

Equipment performance efficiency

performance efficiency of equipment can be determined using the following equation:

$$\eta_{eq} = 100 - wl$$

Where:

η_{eq} **= Efficiency of performance equipment.**

wl **= weight losses (%).**

Specific energy requirement

The specific energy requirement (S.E.R.) was estimated by the following equation

- Specific energy requirement = Total consumed power(kW)/ Equipment capacity (kg/h).

- Total consumed power(kW) = Electrical power+ Thermal power

The required power was estimated by using the following equation (Ibrahime,1982)

Electrical power $= \frac{\sqrt{3} I.V\eta\cos\theta}{1000}$ (kW)

Where, ***P*****: Required power, kW; cos** ***φ*** **= 0.8;** ***I*****: Current intensity, Ampere and** ***V*****: Voltage (380 V).**

Thermal power $= \frac{m.c.\Delta t}{t}$

Where, m: mass, kg ; *C*: specific heat, cal/gm.c°; *Δt*: temperature difference, c°

Operational cost

The operational cost can be determined by using the following formula:

Operational cost (L.E./Mg) = Hourly cost / Production rate

Hourly cost = fixed cost + variable cos

RESULTS AND DISCUSSION

The obtained results will be discussed under the following heads:

Equipment productivity:

Fig. 2 shows the effect of heating temperature and the amount of grains inside the manufactured equipment on equipment productivity. It was noticed that increasing heating temperature led to a decrease in productivity due to increasing operation time with constant feeding weight; as a result of increasing heating period. So, results revealed that, the highest productivity of 13.33 kg.h^{-1} was recorded at a heating temperature of 50 C° and grain amount of 2 kg. while, the lowest productivity is 6 kg.h^{-1} was recorded at a heating temperature of 70 C° and grain amount of 1 kg.

The obtained results indicated that, at 50, 60 C°when the amount of grains inside the equipment increased from 1 kg to 2 kg, the productivity increased (from 12 to 13.3 kg.h^{-1}) and (from 7.5 to 10.9 kg.h^{-1}) respectively. But, by increasing the amount of grains inside the equipment to 3 kg, the productivity decreased .(from 13.3 to 11.25 kg.h^{-1}) and (from 10.9 to 10 kg.h^{-1}) at the same conditions. While, at 70 C° by increasing the amount of grains inside the equipment from 1 to 3 kg, the productivity increased (from 6 to 9 kg.h^{-1}).because the difference in the heating time for 1,2 and 3 kg was small.

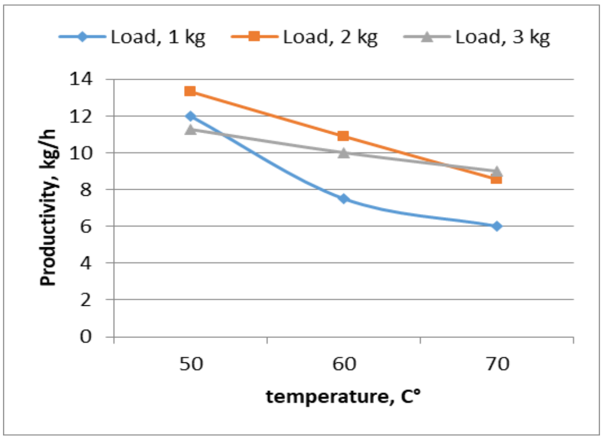

***Fig.* 2. Unit productivity at different temperature degrees under different loads of seeds**

Germination ratio:

Respecting to germination ratio, obtained data as illustrated in Fig. 3 revealed that germination ratio values were 91, 96 and 98 % under the heating temperature of 50 C° with 1, 2 and 3 kg grain amounts, respectively. The decrease in grain amount inside the manufactured unit causes a reduction in grain vitality. Regarding to the effect of heating temperature on germination ratio. It was noticed that by increasing heating temperature from 50 to 70 C°the germination ratio decreased gradually (from 91 to 87%), (from 96 to 92%) and (from 98 to 96%) for 1,2 and 3 kg of grain amount inside the unit. respectively.

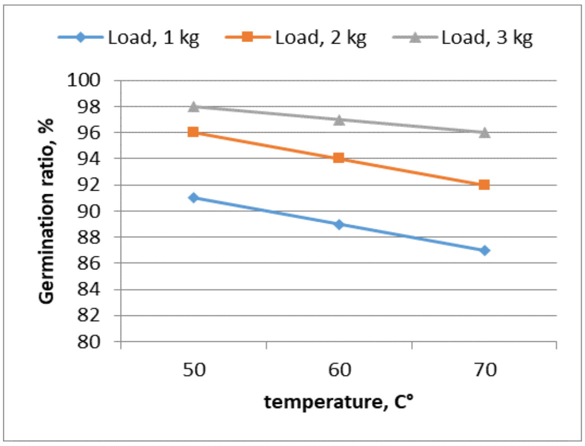

Fig. 3. germination ratio at different temperature degrees under different loads of seeds.

Equipment performance efficiency:

As a general trend, increasing grain amount inside the manufactured unit increased the the weight loss and decreased the equipment efficiency as shown in Fig. (4). The obtained data showed that, weight loss increased from 8 to 9 % and equipment efficiency decreased from 92 to 89 % as the grain amount increased inside the manufactured unit from 1 to 3 kg. during heating temperature of 50 C°.

Also, from obtained results it is clear that the highest and lowest equipment efficiency was 100, 89 % for weight loss of 0, 11% under heating temperature of 70, 50 C° respectively. This was because, the high temperature consumes more time and any increase in heating period was accompanied with a decrease in the weight loss due to the increase in thermal load lead to increases the amount of insect infestation and thereby, decrease in weight loss

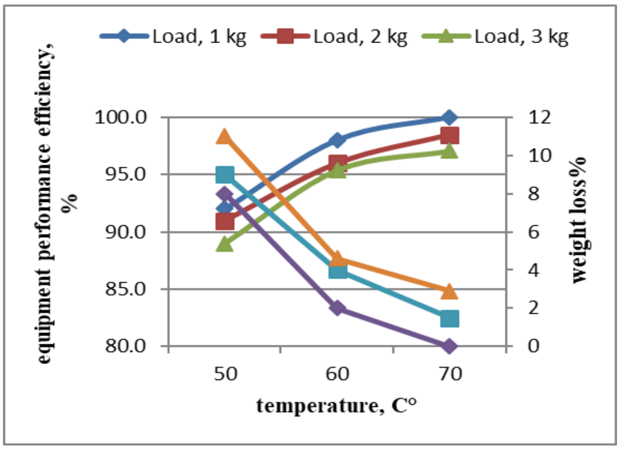

Fig. 4. Unit efficiency and weight reduction at different temperature degrees under different loads of seeds

Specific energy requirement

Related to the consumed energy for the manufactured unit as shown in Fig. 5, results clarified that, by increasing the heating temperature from 50 to 70 C°, the specific consumed energy for disinfestation operation increased from 0.13 to 0.26 kWh/kg, from 0.11 to 0.19 kWh/kg and from 0.12 to 0.18 kWh/kg at 1, 2 and 3 kg of grain amount inside manufactured unit, respectively. This is because of the increment of consumed power and the reduction of productivity due to increasing the heating period Also, it was noticed that the highest specific energy of 0.26 kWh/kg was recorded at grains amount of 1 kg and heating temperature of 70 C°. While, the lowest specific energy of 0.11 kWh/kg was recorded at amount of 2 kg and heating temperature of 50 C°.

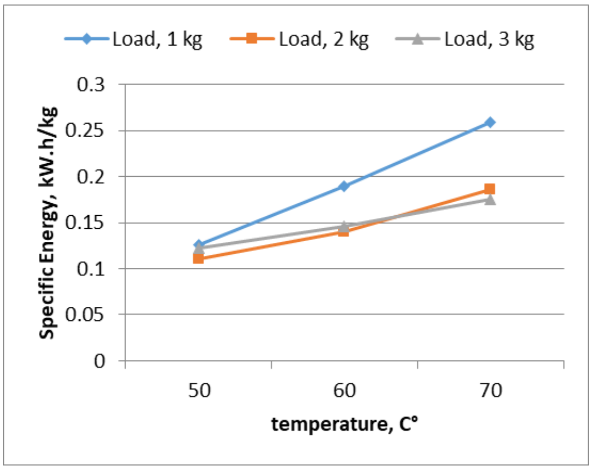

Fig. 5. Specific energy at different temperature degrees under

Operational cost

The critical factor in manufacturing any machine is its price and at the long run its production cost. A complete cost analysis was made at different operating conditions and related with machine productivity. The resulting production cost was found to be affected by both heating temperature and grains amount inside the manufactured. To be more accurate, the production cost was used as an important indicator for selecting optimum operating conditions.

Results in Table 1 illustrate both fixed and variable costs of the manufactured machine reaching to its hourly cost.

Table 1. Cost analysis of the manufactured equipment

Parameters	Fixed cost
Initial cost of thermal unit	8000
Depreciation cost of machine (10 %)	720
Interest cost (12%)	960
Repair and maintenance cost (1%)	80
Total fixed cost per year	1760
Total fixed cost per day (300 operating day/year)	6
Parameters	Variable cost
Labor cost (owner)	0
Electricity cost (1 LE/kw.h)	8
Thermal cost (0.5 LE/kw.h)	4
Variable cost per day	12
Total cost per day	18
Total cost per hour (assume 8h operating hours)	0.75

In addition, FIG 6 illustrated the effect of heating temperature under different amount of grains inside equipment on the production cost.

Results as illustrated in Fig. 6. appeared that the operation cost values were 1.21, 1.12 and 1.34 LE/kg under 50 C° heating temperature, while 1.91, 1.41 and 1.55 LE/kg under 60 C° heating temperature, however the values were 2.52, 1.83 and 1.79 LE/kg under 70 C° heating temperature at grains amount inside equipment of 1, 2 and 3 kg, respectively. It was revealed that the lowest operation cost per kg was obtained at 2 kg amount of grains inside unit at 50 C° heating temperature, while the highest operation cost per kg was obtained at 1 kg amount of grains inside unit at ٧٠C° heating temperature.

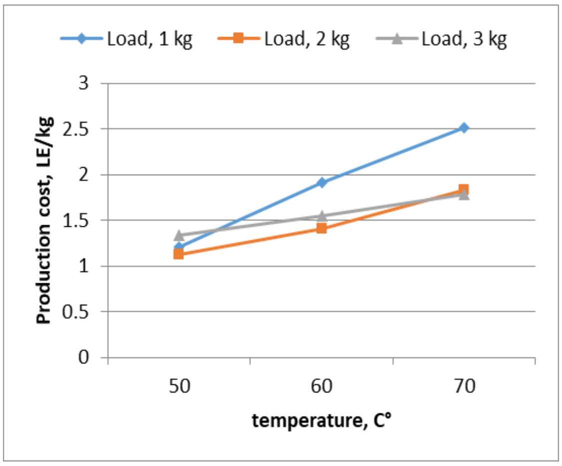

Fig. 6. Specific energy at different temperature degrees under different loads of seeds

REFERENCES

Breiman, A. Graur, D. (1995). Wheat Evaluation. Israel J Plant Sci. 43:58-95.

Caswell, G.H., (1981). Damage to stored cowpeas in Northern Nigeria. Samaru J. Agric., 1: 11-19.

Dermott T. and Evans D. E. (1978) An evaluation of fluidized-bed heating as a means of disinfesting wheat. J. stored Prod. Res. 14, l-12.

Dosland, O., Subramanyam, Bh., Sheppard, K., Mahroof, R., (2006). Temperature modification for insect control. In: Heaps, J. (Ed.), Insect Management for Food Storage and Processing, second ed. American Association of Cereal Chemists, St. Paul, MN, pp. 89e103.

Dupuis, A.S., Fuzeau, B., Fleurat-Lessard, F., (2006). Feasibility of French beans disinfestations based on freezing intolerance of post-embryonic stages of *Acanthoscelides obtectus* (Say). In: Lorini, I., et al. (Eds.), Proceedings of the 9thInternational Working Conference on Stored Products Protection, Campinas(Brazil). Brazilian Post-harvest Association (ABRAPOS), pp. 956-965.

Evans D. E., Thorpe G. R. and Dermott T. (1983) The disinfestation of wheat in a continuous-flow fluidized bed. J. stored Prod. Res. 19, 125-137.

Fields, P.G., (1992). The control of stored-product insects and mites with extreme temperatures. Journal of Stored Products Research 28, 89-118.

Fleurat-Lessard F. (1985) Les traitements thermiques de dtsinfestation des c&tales et des produits drbaliers: PossibilitC d'utilisation pratique et domaine d'application. Bull. OEPP 15, 109-l 18.

Fleurat-Lessard F. (1987) Control of storage insects by physical means and modified environmental conditions. Feasibility and application. In Brit. Crop Prot. Coun. Mono. (Edited by Lawson T. J.), pp. 209-218. London.

Ibrahim, M. K. E.(1982). wet milling of wheat grain M. Sc. Thesis Faculty of agric. Mansoura Univ.

Loganathan, M., Jayasa, D.S., Fields, P.G., White, N.D.G., (2011). Low and high temperatures for the control of cowpea beetle, *Callosobruchus maculatus* (F.) (*Coleoptera: Bruchidae*) in chickpeas. Journal of Stored Products Research 47, 244-248.

Loi, G., Festante, G., (1989). The influence of high and low temperatures on the mortality of adults of *Acanthoscelides obtecus* (Say) (*Coleoptera Bruchidae*). Frustula Entomologica (Pisa) 10, 181-185

Nakakita H (1998) Stored rice and stored product insects. In:Nakakita H (ed) Rice inspection technology manual. ACE Corporation, Tokyo, pp 49–65

تصنيع وتقييم وحدة حرارية على نطاق صغير لمكافحة الحشرات في حبوب القمح المخزونة المصابة

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الملخص

الهدف الرئيسى من هذه الدراسة هو إجراء عملية معاملة حرارية لحبوب القمح المخزونة للحد من وجود آفات التخزين وتقليل فواقد تخزين الحبوب. ولاتمام هذه الدراسة تم تصميم وتصنيع وحدة محلية صغيرة الحجم تعمل على المستوى المعملى والبحثى وتلائم المزارع البسيط تم إجراء تجارب مبدأية ومعايرة لتحديد الزمن اللازم للوصول لدرجة الحرارة المناسبة، ولدراسة كفاءة أداء الوحدة تم استخدام كميات مختلفة من حبوب القمح المخزونة (١ و ٢ و ٣ كجم) على دفعات عند حرارة تسخين (٥٠ و ٦٠ و ٧٠ °م) وتم تقييم الوحدة من حيث نسبة الإنبات والانخفاض الكلى فى وزن الحبوب و إنتاجية الآلة وكفاءة آدائها والطاقة النوعية المستهلكة وتكاليف استخدام الآلة. وقد أسفرت النتائج عن أن المعدل الأمثل لآداء الآلة كان عند دفعة تشغيل ٢كجم وحرارة ٥٠ °م حيث تم الحصول على أفضل إنتاجية ١٣,٣ كجم/ساعة ونسبة إنبات ٩٦% ونسبة إنخفاض فى وزن الحبوب ٩% وكفاءة آداء الوحدة حققت ٩١% وذلك كان مع أقل معدل لاستهلاك الطاقة النوعية ٠,١١ كيلو وات .ساعة/كجم وتكاليف إنتاج١,١٢ جنيه/كجم حبوب معاملة.

الكلمات الدالة: المعاملة الحرارية، فواقد تخزين الحبوب، الطاقة النوعية المستهلكة.