Systematic Design of a Pistachio Hulling Machine

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Abstract

The greatest pistachio producer and exporter country in the word is Iran. Within the fifteen years ago, the average product of this kind of fruit has been 232000 tons per year, which it constitutes almost 52.5% of the world production. Fine processing, post processing and transportation of pistachio, have great effects on its quality, food value, physical properties and marketability of this product. Then any applicable research for processing of pistachio, have direct and indirect effects on developing technology of this industry and as a result, farmers can get more income. In this study, various methods of pistachio hulling using a systematic design method have been carefully investigated and after that, new suitable and multipurpose machine for pistachio processing has been presented that can do hulling, washing and dehydrating processes simultaneously. In order to hull pistachio in this machine, centrifugal force is used. The unit consists of two main parts: the hulling set and the power transmission system. The hulling set consists of a rotating drum and a separate rotating circular base – plate. These two parts rotate in opposite directions, employing two separate electrical motors. Some of the advantages of this new machine are simple mechanisms, avoiding from using any complex part, capability of automation, simple usage, simple maintenance and finally low cost of the machine.

Keywords*: Pistachio, Hulling machine, Systematic design, Centrifugal force*

1 Introduction

Pistachio is an important crop in Iran. Most of the pistachio nuts are exported to countries around the world. For the first time in year 2003, after petroleum, pistachio with 72 thousands tones gained the first score in export goods, bringing 272 million dollars to the country. Iran owns about 48 percent of the pistachio world production, United State, Turkey and Syria are other main producers [2, 4].

Ever-increasing pistachio usage, high food value, production-exportation growth and Iran's portion in world pistachio production, necessitated more investigation and attention toward this product. Mechanized process of pistachio before and after harvesting has great impacts on quality, food value, competitive market and the world production of this strategic product. On the other hand, any analytical

and applicable investigation for the better production process, directly or indirectly, has pronounced effects on farmer's income [11, 12].

The most important procedures conducted when pistachios arrive at the processing plant are: (a) hulling, to separate the soft hull from nuts; (b) trash and blank separation, to remove blank pistachios and trashes such as small branches, remaining shells and leaves; (c) unpeeled pistachios separation, to remove unpeeled and unripe nuts; (d) washing, which involves spraying water at high pressure on the pistachios to clean the nuts; (e) drying, to decrease moisture content of pistachios from 37% to 4% to appropriate level; (f)split nuts separation, to separate split nuts from non-split ones; (h) roasting; and (i) packaging [9].

Based on the researches conducted by the specialists, hulling process of pistachio requires more energy consumption compared to other processes. Consequently, many valuable researches have been carried out about the comparisons of different pistachio hullers throughout the world [6, 7, 8, 10, 11, 13, 14, 15]. Pistachio washing is performed after or simultaneously with the hulling process, while in newly made machines, some injectors are provided to spray water on pistachio [3, 6, 11]. While water spraying, performs the washing, it increases the efficiency of the hullers remarkably [15]. Based on the researches performed by some specialists [5] drying pistachio immediately after washing process has great effects on fungous disease growth reduction such as Aflatoxin.

Generally, in Iran pistachio is hulled by bolt type hulling machines, which are the only commercial type of hulling machines manufactured in the country. Since in bolt type hulling machine pistachio is solely hulled and the subsequent processes, including washing and dehydrating is fulfilled by a long time delay, causing Aflatoxin disease. So, this study was conducted to design a pistachio hulling machine that can do hulling, washing and dehydrating processes simultaneously. The machine is designed on the basis of a systematic design method from mechanical engineering.

2 Literature review

2.1 *Method*

The pistachio hulling machine is designed using a systematic design method described by Pahl & Beitz method [15]. This method belongs to a class of methods using a phase model of the product design process. These methods describe the product design as a process consisting of different phases at different levels of abstraction. The phases are (1) 'problem definition phase', (2) alternatives definition phase' and 'forming phase' (Figure 1). The results of respective phases are a function structure, a concept solution and prototype, respectively.

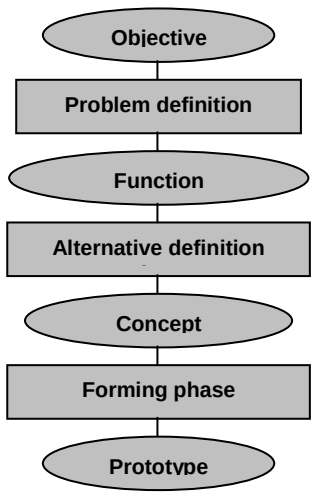

Figure 1: The design process

The problem definition phase starts with defining the objective of the design. In the problem definition phase a set of requirements are established, that can be split into fixed and variable requirements. A design that dose not satisfy the fixed requirements is rejected. Variable requirements have to be fulfilled to a certain extent. To what extent these requirements are fulfilled, determines the equality of the design. The variable requirements are also used as criteria for the evaluation of possible concept solutions. The last part of the problem definition phase consists of the definition of the function of the machine. A function is an action that has to be performed by the machine to reach e specific goal. In our case, important function are charging, hulling, washing, discharging and dehydrating. The functions are grouped in a function structure, which represents a solution on the first level of abstraction (Figure 2). The function structure consists of several functions. Every function can be accomplished by several alternative principles. e.g. mechanical and thermal principles.

In the alternatives definition phase, possible alternative principles for the various functions are presented in a morphological chart (Figure 3). The left column list the functions and the raw display the alternative principles. By selecting one alternative for each function and by combining these alternatives,

concept solutions are established. These concept solutions are represented by font color (red) in the morphological chart. The best concept solution is selected using a rating procedure. In the forming phase the selected concept solution is worked out into a prototype.

2.2 *Pahl & Beitz's view of methods*

Pahl & Beitz is a monumental book that attempts to move engineering work a significant step further in a particular direction. The name of this direction, as indicated by the subtitle, is *systematic*. Before we describe positively what a systematic approach means to Pahl & Beitz, it is useful so indicate some of the non-systematic approaches or ways of working, which Pahl & Beitz set out to improve, or do away with. First of all, Pahl & Beitz want to do away with methods that are too bound up with specialist fields; They want their approach to be broadly applicable, to integrate findings from other disciplines and to facilitate the application of known solutions to related tasks. Non-systematic methods are methods that do *not* lend themselves to the project of building *one* coherent system of methods. On the contrary, Pahl & Beitz stress that design methods should assist broader, system-building efforts, such as "electronic data processing", and "modern management science thinking", i.e. reduction of workload, error, and cost. [Pahl & Beitz:5]. There is, however, a second important sense of 'non-systematic', which Pahl & Beitz want to eliminate. They are critical of methods, that rely on chance, and that do not facilitate the search for optimum solutions (Pahl & Beitz:5). From this it may seem that Pahl & Beitz's systematic approach will, inevitably, be defined as set of instructions that will constrain the user to a very high degree. This however, is not entirely true. Interestingly, Pahl & Beitz, introduces a bit of slack in their systematic approach, with the following remark in a foreword to the Student Edition of their book: "When designing, a balance must be found between an intuitive approach and a systematic one. These two approaches are not exclusive, but are mutually supportive. If, because of experience or a flash of insight, the 'best' solution is found quickly, that is extremely fortunate and there is no reason to work through all the individual steps recommended in this book. However, things seldom happen in that way, particularly when learning about engineering design, and it is helpful to have a clearly defined approach to follow" [Pahl & Beitz 1988:x]. It seems, then, that Pahl & Beitz do recognize that solutions may come from different sources than a systematic approach, but they consider this 'seldom'. At the same time they maintain that the engineer, who follows their systematic approach, is far more likely to find the best solution. Pahl &Beitz's systematic approach is found in the book's central model of the design process, i.e. a design procedure of logical steps raising the chance to find a 'best' solution, and found in the many single step methods in the book, for search, variation, evaluation etc. Pahl &Beitz's procedural approach entails a logical sequence, where the initial 'encircling' of the problem will hold during the subsequent stages. What is also implied is some sort of zooming in, that will eventually 'tighten' into an optimal solution. Again: a systematic approach is something which can be followed – like a road – and it will eventually lead to the desired destination. One might, of course, leave the safe road and enter the unruly terrain, which Pahl & Beitz call 'intuition'. But since the systematic approach is there, stretching out before our feet, it would seem both pointless and hazardous to do anything but to follow the 'systematic approach'.

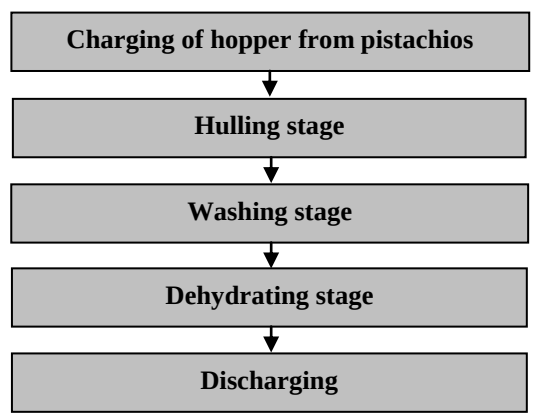

Figure 2: The function structure

2.3 *Application for pistachio hulling machine*

According to the ultimate research objective, formulated as 'design a pistachio hulling machine that can do hulling, washing and dehydrating processes simultaneously', the first step in the problem definition phase was to establish the set of requirements. For this purpose, interviews were held with potential users, scientists and manufactures related to pistachio hulling machine. The resulting requirements are listed below:

Fixed requirements:	*Variable requirements:*
- Producible in sample workhouses. - Competitive with available machines. - Different from available models. - Safety.	- Short time in processing. - Less fraction of kernel. - Longevity of machine. - Consumable power. - Ability in applying pistachios with bunch.

Solution / Function	1	2	3	4	5	6	7	8	9	10	11
Charging of Hopper from Pistachios	Hand	Helix	Belt Conveyor	Gravity Force	Air Pressure	Roller	Feeder Teeth	Cylinder and Piston			
Hulling Stage	Abrasive Rollers	Bolt Type Rollers	Centrifugal Force with Blade	Centrifugal Force with Ragged Surface	Hulling Blades	Threshing unit	Annular Huller	Belt Conveyor Huller	Abrasive Brushes	Jagged Walls	Shaker
Washing Stage (Getting regard of Foreign Material)	Soaking	Rotatory Brushes (Without Water)	Application of Nozzle	Washing in Separating chamber	Nozzle and Roller	Air Pressure					
Dehydrating	Blowing Hot Air	Hot Water Flow into the Hopper Body	Cylindrical Wet-Absorber	Centrifugal Force	Flat Wet-Absorber	Drying in Separating chamber					
Discharging	Hand	Helix	Application of a gate on the Hopper Body	Feeder Teeth	Cylinder and Piston	Belt Conveyor	Moving of Disk	Suction			

Figure 3: Morphologic chart

As it can be seen, possible alternative principles for the various functions are listed in a morphological chart (Figure 3). Five people involved in the project drew lines indicating possible concept solutions in the chart. These concept solutions were then weighted against each other in consultation based on their expert knowledge, using the variable requirements listed above. Examples of these results for hulling stage are presented in Table 1 in the next part.

Table 1: Rating procedure of possible alternative principles for hulling stage

Value / **Function**	Short time in processing	Less fraction of kernel	Producible	Longevity of machine	Consumable power	Ability in applying pistachios with bunch	**Total score**
Abrasive Rollers	0	15	25	2	0	5	**47**
Bolt Type Rollers	10	25	20	5	10	15	**85**
Centrifugal Force with Ragged Surface	15	30	25	5	5	15	**95**
Centrifugal Force with Blade	15	30	25	5	5	15	**95**
Hulling Blades	10	20	20	2	10	15	**77**
Threshing unit	10	10	10	2	0	0	**32**
Annular Huller	10	10	25	5	5	0	**55**
Belt Conveyor Huller	0	10	15	5	5	0	**35**
Abrasive Brushes	5	20	10	2	0	5	**42**
Jagged Walls	10	15	10	2	5	15	**57**
Shaker	**5**	**10**	**10**	**5**	**0**	**15**	**45**

3 The machine

This section describes how the concept solution is worked out in detail. A general view of machine is shown in Figure 4. Modeling and mechanical analysis of machine is performed using solidworks 2007 software and cosmos 2007 software respectively [9]. In order to hull pistachio in this machine, centrifugal force is used. The unit consists of two main parts: the hulling set and the power transmission system. The hulling set consists of a rotating drum and a separate rotating circular base – plate. These two parts rotate in opposite directions, employing two separate electrical motors. The power transmission system of machine is mechanically by belt and pulley, so that they convey power of 3 hp between electrical motors and hulling set. The Washing stage in this machine will be immediately performed after hulling process. In this stage, the rotation of drum will be stopped while rotating circular base – plate will rotate and water will be injected into the drum by nozzle simultaneously. In common methods of pistachio process, dehydrating stage follows the washing one. In the machine presented in this paper, the dehydrating stage is performed without any need for transferring the nuts out of machine to another independent dehydrating machine and consequently helps save time and cost. For performing this stage, both of the electrical

motors rotate in the same direction. Throughout this method, flow of air through the pile of pistachio nuts which comes from the high rotary speed helps dehydrating. In the discharging stage, the rotation of the drum will be stopped while rotating circular base – plate will rotate and discharge gate will be opened.

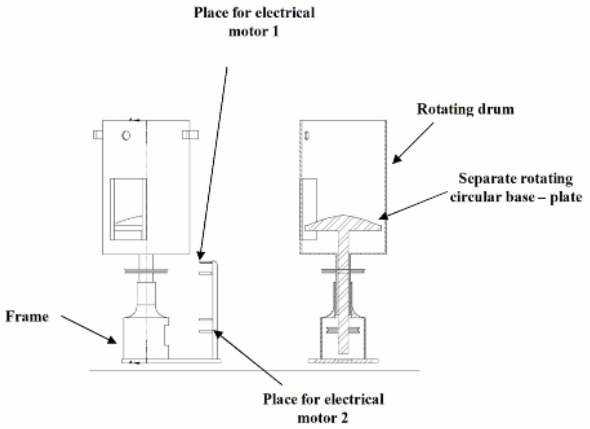

Figure 4: General view of the proposed machine.

4 Discussion and conclusions

Ever-increasing pistachio usage, high food value, production- exportation growth and Iran's portion in world pistachio production, necessitated more investigation and attention toward this product. Mechanized process of pistachio before and after the harvesting has great impacts on quality, food value, competitive market and the world production of this strategic product. Considering the pistachio process, highlights the hulling is the most important process after harvest in pistachio production. In Iran, pistachio hulled by bolt type hulling machine and the subsequent processes, including washing and dehydrating is fulfilled by other machines. These machines made without considering mechanical properties of pistachio that this causes to break considerable percentage of pistachio when hulling, so any analytical and applicable investigation for the better production process, directly or indirectly, has pronounced effects on processing of pistachio. Therefore a centrifugal pistachio hulling machine was designed using a systematic design method that can do hulling, washing and dehydrating processes simultaneously. As part of the machine development efforts, regarding the simple mechanism of belt and pulley for the power transmission, easy and simple assemblage, capability of being equipped with automatic systems for the process and other predicted advantages for the machine, it can reduce a lot the total expenses. Present innovative mechanism can be used for hulling other nuts such as walnut or hazelnut, but with some modification and adaptation in design. Any way researcher can study this proposal for other nuts and after that design and fabricate suitable machine with different capacity. Also waste material discharged from these machines (green hull), can be used for colors industry or others industry.

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