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Design, development and evaluation of a divergent roller sizer for almond kernels

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Introduction: Iran is one of the major producers of almonds. According to the statistics released by FAO (2011), Iran with more than 110000 tons of almonds is the third in rank throughout the world. However, most Iranian almonds are presented as an unsorted and unpackaged product. Some producers sort their products by hand which is very time-consuming and labor-intensive. So, there is an essential need for suitable grading and packaging machines especially for the export of almond kernels.Grading, which is sometimes called sorting, is basically separating the material in different homogenous groups according to its specific characteristics like size, shape, color and on the basis of quality. Weighing is one of the best methods for grading agricultural products based on size, but due to its high cost and complexity of operations, usage of weigh size sorting machines is practically limited. So, sizing of most agricultural products is accomplished based on their dimensional attributes such as diameter, length, thickness or a combination of them. Field study shows that recently vibrating sizing machines are used for grading almond kernels. This type of sizing machine is huge, expensive, noisy and it consumes a lot of energy. Thus, the main objective of the present study was the design, development and evaluation of a new prototype of an almond kernel sizing machine.

Materials and methods: It is important that the machine could resolve defects of existing vibrating machines. It should provide efficient and cost effective sizing for a wide range of kernel sizes and shapes. Furthermore, it should be of simple construction and be able to accept manual feeding. Previously conducted experiments showed that the thickness of the kernel is the most appropriate dimension for its sizing. Among the different types of dimensional sizing machines, the divergent roller grader which grades the products based on their thickness is considered to be one of the simplest options. So, a divergent roller grader was developed and built in this research. The prototype consisted of two diverging rotating rollers which were made of mild steel with an outside diameter of 95 mm and a length of 700 mm. They were mounted to provide an adjustable slope towards the wide opening end. These roller beds were fixed on a box shaped frame of size 500×1000×1200 mm. The slope and counter-rotating action of the rollers encouraged the kernels to continue moving toward the end where the gap between the rollers was the widest. A tray was fixed at the feeding end of the machine for feeding the kernels. A provision was given to adjust the gap from a minimum to a maximum level. Based on the required activate torques of the rollers, an electric 74 W motor was selected to drive the machine. The power transmission mechanism consists of two pulleys 150 and 250 mm diameters and a V belt type A with a length of 1448 mm. The center distance of the pulleys is calculated to be 410 mm. Standard criterions of weighted sorting error index ($\bar{C}_R$), weighted sorting efficiencies index (E_W) and operation capacity (Q) were used to evaluate the machine. Practical analysis showed that the machine's performance is influenced mainly by the slope of the rollers, the rotation speed of the rollers, and the feeding rate of the product. In order to evaluate the performance of the prototype, a factorial experiment in a completely randomized design with three replications for each test was done. The performance evaluation was carried out for three levels of feeding rates (600, 1000, and 1400 kg $8h^{-1}$, three levels of slopes (2, 7, and 12 degree), and three rotation speeds of rollers (50, 80, and 110 rpm). Spreadsheet software MSTATC and SPSS were used to analyze the data and the Duncan's multiple range tests were used to compare the means.

Results and discussion: Analysis of variance showed that all three studied factors have significant effects on evaluating standard criterions of $\bar{C}_R$, EW, and Q at the 1% level of confidence. In this work, an increase in the slope of rollers led to a decrease in $\bar{C}_R$, whereas at the same time an increase in E_W and Q was observed. It may be because at a higher level of slope the almond kernels slip more effectively on rollers surface. This condition restrains the aggregation of kernels on the first part of the gap between the rollers. So, they have enough time to drop through all of the gap. Experimental results show that as the feeding rate increases, $\bar{C}_R$ and Q increase, whereas E_W decreases. Based on the

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results of the experiments, with an increase of rotation speed of rollers from 50 to 110 rpm, the $\bar{C}_R$ decreases up to %6.5, and E_W decreases about %6. Study of interactions showed effects among which only the interaction of slope and rotation speed of rollers significantly affects all standard criterions. The results also showed that the operation capacity (Q) was significantly affected ($P \leq 0.01$) by the interaction effects between the feeding rate and the slope of rollers, and the feeding rate and the rotation speed of the rollers. The mechanical damage to almond kernels in the form of external damage such as cracks and scuffing was almost zero, which is a very important advantage of this machine in comparison with the other sizing machines.

Conclusions: In this research, a divergent roller sizer was designed, developed and evaluated for almond kernels.The results showed that the best machine operation is obtainedat a feeding rate of 1000 kg $8h^{-1}$, slope of 9 degrees and rotation speed of 110 rpm. In this situation, the prototype could reach weighted sorting efficiencies index of 80% and operation capacity of 830 kg in an 8 hour work shift with weighed sorting error index of 23%.

Keywords: Almond kernel, Design and development, Sizing, Sorting, Roller sizer