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DESIGN, FABRICATION AND EVALUATION OF A MOISTURE-BASED FIG SORTER

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ABSTRACT

The main objective of the study is to design and fabricate a moisture-based fig sorter. Based on some physical properties of fig fruit which are affected by moisture content, the coefficient of static friction and rolling resistance were introduced as the key characteristics in fig sorting. Considering the mentioned characteristics, a test rig was fabricated. The rig consists of a horizontal feeding belt and three inclined sorting belts driven by an electric motor. The angle of each sorting belt can be manually adjusted. In order to evaluate the sorter, freshly harvested figs having different moisture contents were fed into the sorter. A factorial experiment with two factors including four levels of belt speed (7.2, 8.4, 9.4 and 10.6 $m \cdot min^{-1}$) and 9 levels of belt slope arrangements (8, 9, 10 – 8, 9, 11 – 8, 9, 12 – 8, 10, 11 – 8, 10, 12 – 9, 10, 11 – 9, 10, 12 – 9, 11, 12 – 10, 11, 12 degree) were conducted in a completely randomized design in four replications. A sorting index was introduced to show the performance of the sorter. Results have shown that the belt slope arrangement and belt speed both have highly significant effect on sorting accuracy. The best sorting accuracy of about 80% was obtained at belt speed of 9.4 $m \cdot min^{-1}$ and belt slope arrangement of 8, 9, 10 degrees.

Key words: fig, sorter, physical properties, coefficient of friction, rolling angle

NOMENCLATURE

M – mass, kg

V_b – belt speed, $m \cdot s^{-1}$

r – rolling radius, m

$\bar{I}$ – mass moment of inertia, $kg \cdot m^2$

μ_s – coefficient of static friction, decimal

μ_k – coefficient of dynamic friction, decimal

$\bar{a}$ – acceleration of mass center, m·s^{-2}

α – angular acceleration, rad·s^{-2}

R – rolling resistance, N

N – normal surface reaction, N

θ – inclination angle of belt, degree

l – belt length, m

X_b – distance traveled by belt, m

X_f – distance traveled by fig on belt, m

X_e – stagnation distance of fig on belt, m

t – time, s

N_t – total number of figs

N_A – number of figs belonged to the moisture group A

N_B – number of figs belonged to the moisture group B

N_C – number of figs belonged to the moisture group C

N_D – number of figs belonged to the moisture group D

$n_{a,total}$ – total number of figs dropped in A basket

$n_{b,total}$ – total number of figs dropped in B basket

$n_{c,total}$ – total number of figs dropped in C basket

$n_{d,total}$ – total number of figs dropped in D basket

$n_{a,dropped}$ – number of figs dropped in each basket from group A

$n_{b,dropped}$ – number of figs dropped in each basket from group B

$n_{c,dropped}$ – number of figs dropped in each basket from group C

$n_{d,dropped}$ – number of figs dropped in each basket from group D

$\bar{l}_{accuracy}$ – average accuracy index of sorter

$l_{accuracy,A}$ – accuracy index of group A

$l_{accuracy,B}$ – accuracy index of group B

$l_{accuracy,C}$ – accuracy index of group C

$l_{accuracy,D}$ – accuracy index of group D

INTRODUCTION

Fig has a fairly good nutritious value which contains sugar, starch, fat, cellulose, minerals and water. The nutritious value of a dry fig is more than that of a fresh fig because it has lost some water which has no nutritious value. Iran produced 88,000 tons of dried figs (Ficus carica L. cv. Sabz) in 2006. In respect to cultivated area, after Portugal, Egypt and Turkey, Iran ranks fourth in the world. With regard to the amount of production, after Egypt and Turkey, Iran possesses the 3th rank in the world [8].

In Iran, much of the product is downgraded due to traditional methods of harvesting and drying in which producers let the figs dry on trees until they fall down on the ground. This method of harvesting is laborious, time consuming, and somehow unhygienic. In order to prevent damages associated with traditional harvesting, shake harvesting would be a good option for mechanized fig harvesting, but in this method harvested figs have different moisture content. To dry the figs appropriately, a suitable sorter should be designed to sort the harvested figs based on their moisture content.

Some methods and devices are introduced for sorting fruits and vegetables in agricultural process engineering, such as screens, diverging belts, roller sorters and weight sorters. Also in order to sort grain, nuts and seeds, using of screens, pneumatic, gravitational, spiral, disk and cylinder separators can be useful based on the properties of products [11].

An automatic electro optical sorter was designed to eliminate BGY (Bright Green Yellow) fluorescent pistachio nuts [9]. Elster and Goodrum used machine vision to detect the cracks in eggs [7]. Their system was able to recognize the cracks 96% of the time. By using a multi camera and multiprocessor system with a suitable algorithm a high speed sorting system was developed for dried prunes [4]. Ozer et al. [20] used a fusion classification technique for sensing fruit maturity. They used sensors data as inputs to a recurrent auto associative memory to classify the fruits into four maturity stages. Their method was very successful in sensing maturity of cantaloupes. Defects segmentation was handled on Golden Delicious apples by Leemans et al. [17]. They manipulated a color machine vision to detect the defects by comparing the color of samples with the model. A fuzzy logic model was conducted for predicting peanut maturity based on NMR-signal and days after planting [21]. A non-destructive impact test was conducted by Jaren and Garcia-padro for sorting fruits according to their firmness and software [13]. A method was introduced for measuring date moisture content in which a simple electronic circuit was used to sense the voltage response as the date was held in contact with the moisture sensor [12]. An apple grading system was fabricated to grade apples by fuzzy logic methods with accuracy of 89% [15]. Urbano Bron et al. studied chlorophyll fluorescence as a tool to evaluate the ripening of Golden papaya fruit [26]. They determined that this non-destructive method might assist the evaluation of fruit ripeness. A modern technique of time resolved reflectance spectroscopy was used to assess the maturity of nectarines. With this technique the light absorption at 670 nm in the fruit flesh was measured and a kinetic model was used as a biological shift factor to express firmness reduction during ripening [25]. A developed sensor based on the analysis of fruit impact force on a load cell in a pre-commercial sorting line was described by Gutierrez et al. [10]. They successfully classified peaches into three groups (very firm, firm and not firm) with 80% repeatability. Citrus sorting was investigated by using multispectral computer vision based on identification of the most common defects [3]. A machine vision system is developed in order to grade dates automatically by using a digital reflective near infrared imaging [16]. Jarimopas and Jaisin developed an experimental machine vision system to sort sweet tamarind [14]. This system can sort sweet tamarinds by using image processing techniques based on their shape, size and defects. An automatic sorting system by using computer vision and morphological features was developed for sorting of Satsuma segments. This system was able to divide the Satsuma into different groups based on the amount of breakage with 93.2% accuracy [2]. Tabatabaei and Hashemi utilized a rotational plate with inclined semi conical edges in order to grade citrus [23]. They employed centrifugal and gravitational forces to achieve this goal. Terdwongworakul et al. have used physical, mechanical, physiological and acoustic properties of coconuts to determine their maturity levels [24]. Another way to assess fruit quality is using visible/near infrared spectroscopy. Sun et al. have manipulated this approach in order to determine fruit quality [22].

As far as we know there is no information available on fig sorting based on moisture content. Therefore the objective of this study is to design, fabricate and evaluate a moisture-based fig sorter.

MATERIAL AND METHODS

The figs used in the study were harvested manually from fig orchards of Estahban valley in Fars Province in September 2009. The harvested figs were sorted into four groups based on their moisture content and sealed in zip lock polythene bags and stored in a refrigerator at 5°C for 48 h to ensure uniform moisture distribution. Moisture content of samples randomly taken from each group was determined using oven method [1]. The moisture contents were (32.5–34.4), (43.9–45.7), (61.4–62.4), and (74.2–75.2) (%w.b.) for groups 1, 2, 3 and 4, respectively. Before each experiment, the figs were kept in the polythene bags at room temperature for five hours to equalize with ambient temperature [5]. In order to design a moisture-based figs sorter some physical properties affected by moisture content are to be known. Based on comprehensive experiments it was concluded that sphericity, coefficient of static friction and rolling resistance are moisture dependent properties and therefore they are introduced as the key characteristics in fig sorting [18].

For calculating the sphericity, the length, width and thickness of 10 fig samples from each moisture group was measured individually, and the sphericity was found to be 90 to 94 percent.

The coefficient of static friction of fig in each moisture group was found on rubber surface by using an adjustable inclined table [6, 19]. The table was gently raised and the angle of inclination at which the figs started sliding were read as 42.93, 46.77, 47.44 and 43.92 degree for group 1, 2, 3 and 4, respectively. The tangent of the angles was introduced as the coefficient of static friction [18].

For measuring the rolling resistance of a fig on a rubber surface, a fig was placed on the surface of a rubber-coated table and the angle of inclination at which the fig started rolling was reported as the angle of rolling resistance which were 13, 13.75, 14.40 and 14.7 degree for groups 1, 2, 3 and 4, respectively [18].

Theory

Regarding mentioned experiments, it was concluded that moisture content has significant effect on coefficient of static friction and rolling resistance.

Before designing a sorter which works based on these two physical properties, theory of motion of an object on a moving slopped surface was studied (Fig. 1).

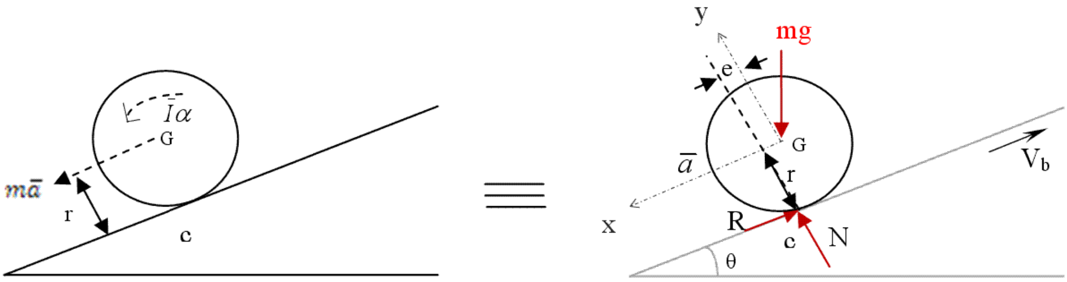

Figure. 1. Free body diagram of a fig on a sloped belt

It was assumed that fig is spherical in shape (average sphericity of 92%) rolls without slipping, so that $\bar{a} = r\alpha$. In addition, it was assumed that wet figs deform when rolling down so that the reaction vector acts along the line which do not contain the center of sphere (Fig. 1), in this situation we have:

$$\sum F_x = m\bar{a}_x \rightarrow mg\sin\theta - R = m\bar{a} \tag{1}$$

$$\sum F_y = m\bar{a}_y = 0 \rightarrow N = mg\cos\theta \tag{2}$$

$$\sum M_G = \bar{I}\alpha \rightarrow Rr - mge\cos\theta = \frac{2}{5}mr^2\alpha \rightarrow R = \frac{2}{5}mr\alpha + \frac{mge}{r}\cos\theta \tag{3}$$

Substituting eq. 3 into eq. 1 gives:

$$mg\sin\theta - \frac{2}{5}mr\alpha - \frac{mge}{r}\cos\theta = m\bar{a} \rightarrow \bar{a} = g\sin\theta - \frac{2}{5}r\alpha - \frac{ge}{r}\cos\theta \tag{4}$$

$$r\alpha = \bar{a} \rightarrow \bar{a} = g\sin\theta - \frac{2}{5}\bar{a} - \frac{ge}{r}\cos\theta \rightarrow \frac{7}{5}\bar{a} = g\sin\theta - \frac{ge}{r}\cos\theta \rightarrow \bar{a} = \frac{5}{7}g\left(\sin\theta - \frac{e}{r}\cos\theta\right) \tag{5}$$

Alternatively, with our assumption of $\bar{a} = r\alpha$ for pure rolling, a moment sum about C, gives $\bar{a}$, directly. Thus:

$$\begin{aligned}&\sum M_C = \bar{I}\alpha + m\bar{a}r \rightarrow mgr\sin\theta - mge\cos\theta = \frac{2}{5}mr^2\alpha + m\bar{a}r\\ &\rightarrow g(r\sin\theta - e\cos\theta) = \frac{2}{5}r\bar{a} + \bar{a} = \frac{7}{5}r\bar{a} \rightarrow \bar{a} = \frac{5}{7}g\left(\sin\theta - \frac{e}{r}\cos\theta\right)\end{aligned} \tag{6}$$

To check our assumption of no slipping, we calculate *R*, *N*, and compare *R* with its limiting value. From eq. 1:

$$R = -m\bar{a} + mg\sin\theta = \frac{mg}{7}\left(2\sin\theta + 5\frac{e}{r}\cos\theta\right) \tag{7}$$

and

$$N = mg\cos\theta \tag{8}$$

But the maximum possible friction force is:

$$R_{\max} = \mu_s N = \mu_s mg\cos\theta \tag{9}$$

If $R \prec R_{\max}$ our assumption is right.

If $R \succ R_{\max}$ then our assumption of pure rolling is wrong, therefore, the fig slips as it rolls and $\bar{a} \neq r\alpha$, the friction force or rolling resistance become:

$$F = \mu_k N = \mu_k mg\cos\theta \tag{10}$$

The motion equation becomes:

$$\sum F_x = m\bar{a}_x \rightarrow mg\sin\theta - \mu_k mg\cos\theta = m\bar{a} \rightarrow \bar{a} = g\sin\theta - \mu_k g\cos\theta \quad (11)$$

$$\sum M_G = \bar{I}\alpha \rightarrow \mu_k mgr\cos\theta - mge\cos\theta = \frac{2}{5}mr^2\alpha \rightarrow \alpha = \frac{5}{2}\left(\frac{g\cos\theta}{r}\right)\left(\mu_k - \frac{e}{r}\right) \quad (12)$$

The time required for fig to move $x(m)$ from rest with constant acceleration would be obtained as:

$$X_f = \frac{1}{2}\bar{a}t^2 \rightarrow t = \sqrt{\frac{2X_f}{\bar{a}}}, \quad X_b = V_b t \quad (13)$$

Criterion for separation by considering X_e (Fig. 2):

If $X_b - X_f \geq X_e \rightarrow$ fig will be carried up by belt (14)

If $X_b - X_f \leq X_e \rightarrow$ fig rolls down on the belt. (15)

From equations 1, 13, 14 and 15:

$$X_b - X_f \geq X_e \rightarrow V_b t - \frac{1}{2}at^2 = V_b t - \frac{1}{2}\left(g\sin(\theta) - \frac{R}{m}\right)t^2 \geq X_e \quad (16)$$

$$X_b - X_f \leq X_e \rightarrow V_b t - \frac{1}{2}at^2 = V_b t - \frac{1}{2}\left(g\sin(\theta) - \frac{R}{m}\right)t^2 \leq X_e \quad (17)$$

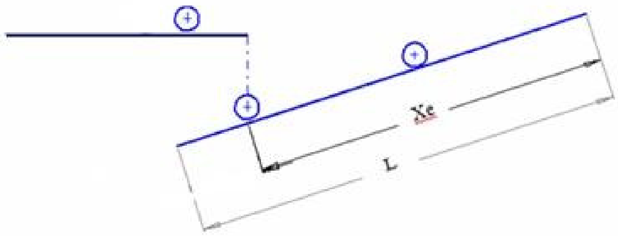

Fig. 2. Stagnation distance of fig on a sorting belt

If belt speed (V_b), time of separation (t), and stagnation distance of fig on belt (X_e) are known, the inclination angle of each belt (θ), for separation of figs having different moisture content can be determined.

Based on dynamic analysis it was concluded that proper combination of different belt speeds and belt angles can be used for sorting process of figs at different moisture content levels.

Design and fabrication

Considering the theoretical analysis and using the experimental values of coefficient of static friction and rolling resistance for each group of figs, using a sorter equipped with a set of belt conveyor system with capability of adjusting belt angles and speeds was suggested.

Because of having four groups of moisture content, a triple-slopped belt sorter equipped with a horizontal feeding belt was designed and fabricated (Fig. 3).

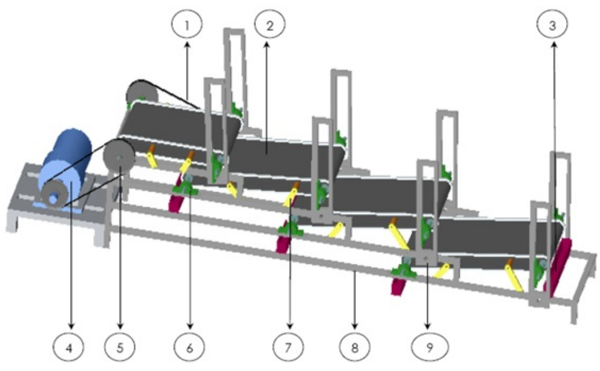

Fig. 3. Schematic diagram of sorter: 1 – power transmission belt, 2 – belt conveyor, 3 – basket, 4 – electric motor, 5 – driven pulley, 6 – fixed journal bearing, 7 – idler roller, 8 – chassis, 9 – slotted support

The inclination angle of each belt can be adjusted manually by sliding the rollers along the slotted supports. A basket was placed at the beginning of each belt as well as at the end of the last belt to collect the sorted figs. Each belt overlaps the next one, so the figs which do not drop into the basket would drop on the next belt. The length of each belt is 75 cm. In order to prevent dropping down the figs from the belt sides, four conical idler rollers were installed at both sides of each belt to raise them up.

Test rig was powered by a 2.2 kW continuous variable speed electric motor. By using an electric volume control on a digital board, the speed of the motor could be varied continuously from 0 to 1400 rpm.

The main chassis was made of rectangular steel tube sections (10×30 mm). To lighten the moving parts and reduce energy losses, the supporting rollers of the belts were constructed with 40 mm diameter circular aluminum tube section. Each roller was supported by two ball bearings to reduce the friction in moving parts. Transmission of power from the motor shaft to each belt was done through a V-belt drive system.

Test and evaluation of the rig

To evaluate the test rig for sorting process, several inclination angles and belt speeds must be selected. According to the theoretical analysis and the experimental values of fig properties as well as assuming the sorting duration to last between 5–10 s for the figs having different moisture contents and by choosing the belt inclination angle of 8 to 12 degree, the speed of belts for sorting process would be obtained between 6 to 12 m·min^{-1}. The weight of figs in different moisture group does not change significantly and are within 6–12 g. Therefore the sorting performance is very sensitive to belt speed and belt angle. By running an extensive sorting experiment from various combinations of belt angles (8–12°) and belt speeds (6–12 m·min^{-1}) it was concluded that some angles and speeds were not suitable for sorting. To show the variability of sorting performance and evaluate the sorter, a factorial experiment with 2 factors including four levels of belt speed (7.2, 8.4, 9.4, 10.6 m·min^{-1}) and 9 levels of belt slope arrangements (8_i, 9_j, 10_k – 8_i, 9_j, 11_k – 8_i, 9_j, 12_k – 8_i, 10_j, 11_k – 8_i, 10_j, 12_k – 9_i, 10_j, 11_k – 9_i, 10_j, 12_k – 9_i, 11_j, 12_k – 10_i, 11_j, 12_k degree) was conducted in a completely randomized design in four replications (i, j and k indicate slope of second, third and fourth belt, respectively). Ten freshly harvested figs from each moisture content group were randomly selected and mixed together and then fed into the sorter. According to the discussed theory, some figs are expected to move down and the others are carried up and fall on the next belt. At the end of the test, figs collected in the basket under each belt were counted. It was seen that some figs from other groups were fallen into a basket which has not belonged to that group. In order to evaluate the performance of sorter, using fuzzy logic analysis is essential. Therefore, the figs which were not from the expected group were counted and placed in a performance formula with a special weight. For this study there are four groups of moisture contents which should be separated. So, there are 3 unwanted groups in each basket. In order to evaluate the designed sorter better, some weights were defined for those groups which do not belong to the specific basket. These weights are 0.66 for figs from the nearest group to the expected group, 0.33 for figs from the second nearest group to the expected group and zero for the farthest group to the expected group (Fig. 4.). Therefore the accuracy index for each group of moisture content is calculated as:

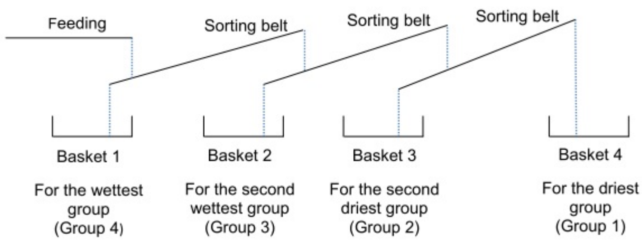

Fig. 4. Schematic diagram of four groups of moisture contents and their baskets

For basket A:

$$\text{if } n_{a,total} \le N_A \rightarrow l_{accuracy,A} = \frac{n_{a,dropped} + 0.66 n_{b,dropped} + 0.33 n_{c,dropped}}{N_A} \cdot 100 \tag{18}$$

$$\text{if } N_A < n_{a,total} \le 2N_A \rightarrow l_{accuracy,A} = \frac{n_{a,dropped} + 0.66 n_{b,dropped} + 0.33 n_{c,dropped}}{n_{a,total}} \cdot 100 \tag{19}$$

$$\text{if } n_{a,total} > 2N_A \rightarrow l_{accuracy,A} = 0 \tag{20}$$

For basket B:

$$\text{if } n_{b,total} \le N_B \rightarrow l_{accuracy,B} = \frac{0.66 n_{a,dropped} + n_{b,dropped} + 0.66 n_{c,dropped} + 0.33 n_{d,dropped}}{N_B} \cdot 100 \tag{21}$$

$$\text{if } N_B < n_{b,total} \le 2N_B \rightarrow l_{accuracy,B} = \frac{0.66n_{a,dropped} + n_{b,dropped} + 0.66n_{c,dropped} + 0.33n_{d,dropped}}{n_{b,total}} \cdot 100 \quad (22)$$

$$\text{if } n_{b,total} > 2N_B \rightarrow l_{accuracy,B} = 0 \quad (23)$$

For basket C:

$$\text{if } n_{c,total} \le N_C \rightarrow l_{accuracy,C} = \frac{0.33n_{a,dropped} + 0.66n_{b,dropped} + n_{c,dropped} + 0.66n_{d,dropped}}{N_C} \cdot 100 \quad (24)$$

$$\text{if } N_C < n_{c,total} \le 2N_C \rightarrow l_{accuracy,C} = \frac{0.33n_{a,dropped} + 0.66n_{b,dropped} + n_{c,dropped} + 0.66n_{d,dropped}}{n_{c,total}} \cdot 100 \quad (25)$$

$$\text{if } n_{c,total} > 2N_C \rightarrow l_{accuracy,C} = 0 \quad (26)$$

For basket D:

$$\text{if } n_{d,total} \le N_D \rightarrow l_{accuracy,D} = \frac{0.33n_{b,dropped} + 0.66n_{c,dropped} + n_{d,dropped}}{N_D} \cdot 100 \quad (27)$$

$$\text{if } N_D < n_{d,total} \le 2N_D \rightarrow l_{accuracy,D} = \frac{0.33n_{b,dropped} + 0.66n_{c,dropped} + n_{d,dropped}}{n_{d,total}} \cdot 100 \quad (28)$$

$$\text{if } n_{d,total} > 2N_D \rightarrow l_{accuracy,D} = 0 \quad (29)$$

Finally, the average sorting accuracy index for the designed sorter is calculated as:

$$\bar{l}_{accuracy} = \frac{N_A \cdot l_{accuracy,A} + N_B \cdot l_{accuracy,B} + N_C \cdot l_{accuracy,C} + N_D \cdot l_{accuracy,D}}{N_t} \quad (30)$$

Where N_t is sum of the figs from different moisture content groups:

$$N_A + N_B + N_C + N_D = N_t \quad (31)$$

RESULTS AND DISCUSSIONS

Based on the theoretical analysis it was shown that belt speed and belt slop both have effect on sorting performance and again from variance analysis of sorting accuracy data (Tab. 1), it was found that belt speed, belt slop and their interaction have significant effect on fig sorting ($P < 0.01$).

Table 1. Analysis of variance for the effect of belt speed and belt slope arrangement on sorting accuracy

Source	Sum of squares	d*f*	Mean square	*F*
Speed	6459.57	3	2153.19	122.14**
Arrangement	24937.59	8	3117.20	176.82**
Arrangement * speed	4050.62	24	168.78	9.57**
Error	1269.31	72	17.63	
Corrected total	340604.25	108		

** Significant at $P < 0.01$.

A comparison of the mean values of calculated accuracy index for different combinations of belt speeds and belt slope arrangements are shown in Table 2. The results show that sorting accuracy is significantly dependent on both belt slop and speed. The lowest accuracy of about 19% belongs to the belt speed of 7.2 m·min^{-1} and belt slope arrangement of (10_i, 11_j, 12_k) whereas the highest sorting accuracy of about 80% was achieved at belt speed of 9.4 m·min^{-1} and belt slope arrangement of (8_i, 9_j, 10_k). Generally for belt speeds of 7.2, 8.4, and 9.4 m·min^{-1}, the sorting performance follows a decreasing trend when belt slop increases, while such a trend is not observed at the belt speed of 10.4 m·min^{-1}. This could be attributed to the fact that at a constant belt speed, when sorting belt angles are set at higher values, the figs tend to roll down the belts at progressively higher speeds instead of being curried up by the belts. At maximum belt speed of 10.6 m·min^{-1} the sorting accuracy first increases from 60.99 to 73.24% when belt arrangement varies from 8, 9, 10 degree to 8, 10, 11 degree, and then starts a decreasing trend by farther increase in belt slopes. The increase of sorting accuracy in the first range of angles is due to the positive effect of higher belt speed to curry up the figs, while farther increase in belt slopes counteracts and progressively neutralizes the positive effect of higher belt speeds on sorting performance.

Table 2. Comparison of mean accuracy index (%) at different belt slop arrangements for each belt speed. (Duncan, $\alpha < 0.05$)

Arrangement	Speed (m·min^{-1})			
	7.2	8.4	9.4	10.6
$8_i, 9_j, 10_k$	65.35 ^{a}	68.68 ^{a}	79.28 ^{a}	60.99 ^{b}
$8_i, 9_j, 11_k$	60.01 ^{b}	64.30 ^{b}	70.94 ^{b}	68.31 ^{ab}
$8_i, 9_j, 12_k$	57.16 ^{b}	61.91 ^{b}	69.98 ^{b}	69.83 ^{ab}
$8_i, 10_j, 11_k$	58.57 ^{b}	61 ^{b}	69.88 ^{b}	73.24 ^{a}
$8_i, 10_j, 12_k$	57.43 ^{b}	60.16 ^{b}	61.69 ^{c}	71.74 ^{ab}
$9_i, 10_j, 11_k$	27.35 ^{c}	34.53 ^{c}	61.23 ^{c}	62.51 ^{ab}
$9_i, 10_j, 12_k$	24.27 ^{c}	30.35 ^{c}	56.66 ^{c}	65.19 ^{ab}
$9_i, 11_j, 12_k$	23.76 ^{c}	24.66 ^{e}	43.58 ^{d}	49.28 ^{c}
$10_i, 11_j, 12_k$	18.75 ^{d}	20.15 ^{e}	21.51 ^{e}	35.30 ^{d}

Means followed by similar letters in each column are not significantly different at 5% level.

The effect of belt speed at different belt arrangements on sorting performance is illustrated in Figure 5. The bar chart shows that generally, the sorting accuracy increases when belt speed is increased. This figure also shows that sorting performance follows a decreasing trend by progressive increase in belt inclination angle.

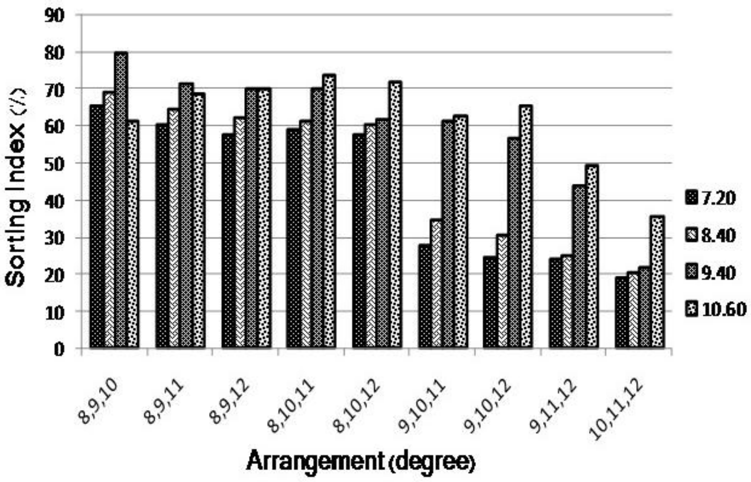

Fig. 5. Effect of belt speeds on sorting accuracy in different belt arrangements

Considering the average weight of figs in different moisture content groups, the mean throughput capacity of about 15.7 kg·h^{-1} was obtained for the designed prototype sorter. By using multiple units next to each or by partitioning the belt width into narrower sorting lanes, the throughput capacity would be increased to desired level.

CONCLUSION

With the aid of the suggested sorter, which is designed based on physical properties of fresh figs it is possible to sort the figs based on their moisture content. The sorting performance is highly dependent on belt speed and slop and therefore it is necessary to select the appropriate combination of these two machine parameters to accomplish accepted sorting performance. The sorter works with reasonable sorting accuracy of about 80% which can be useful to reduce post-harvest losses and increase post-harvest efficiency. In the suggested sorter, the speeds of sorting belts are the same for a run. It is suggested to modify the driving system of sorting belts in order to have different belt speeds for different sorting belts in any specific run. This modification will increase the flexibility of sorter and as a result the sorting accuracy may be improved.

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