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Some physical properties of apricots and testing apricot sorting machines

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Summary: Examinations were carried out in the manipulating and packaging plant of Gyümölcsért Ltd, in Boldogkőváralja, to determine some physical properties of five apricot cultivars and to test the work quality of the apricot sorting machines. The size and the weight of the fruits were measured and two sorting machines were tested. The results are given in tables and diagrams. The conclusions are also summarised.

Key words: apricot cultivars, physical properties, sorting, operating characteristics

Introduction

The main objectives of this research work were to determine some physical properties of apricots and the effect of the physical characteristics of the apricot cultivars on the quality of grading. The classification accuracy of the sorting machines with different apricot cultivars and the classification performance of the machines with different apricot cultivars were also examined based on our previous works (*Ancza et al.* 2011; *Polyák and Csizmazia,* 2003; *Polyák et al.* 2010 and 2011).

Material and methods

The physical characteristics of the following five domestic and foreign apricot cultivars were determined:

1. Hungarian apricot
2. Jumbo Cot
3. Bergerouge
4. Bergeron
5. Late Jumbo

From each cultivar 50–50 pieces of fruit (3–4 typical fractions were analyzed) were chosen and then measured.

The following data were recorded:

1. the main sizes of the fruits in three orthogonal dimensions with a digital slide gauge, with an accuracy of 0.01 mm;
2. the weight of each fruit with an accuracy of 0.01 g;
3. the weight ratio of the total, the sorted and the graded fruits;
4. the operating characteristics of the machines.

The sorting machines

There are two Compac type (New Zealand) sorting machines in the plant: a one-line, with a weight capacity of 0,8–1,2 t/h and a three-line, with a weight capacity of 2–3 t/h. Before the procedure the fruit is chilled to 8 ºC, and then it is loaded by hand, tilting the container gradually *(Figure 1).* There is a selector in front of the machine to select the undersized fruit and the contamination. During the manual selection the overripe, the green, the deteriorated and the damaged fruits are selected. The roller sorting table *(Figure 2)* makes possible the careful selection of the fruit by turning it around.

From the sorting machine the fruit gets to a multi-line roller feeder through rotating brush rollers *(Figure 3),* which organizes the fruits to a classifying belt *(Figure 4).*

The speed of the multi-line roller feeder and the classifying belt is adjustable and is consistent with the chain speed moving the roller cars. The sorting machine is started at a small start-up performance, to check the correct operation of the machine, and then the performance will increase as long as it does not go to the expense of quality, or even what the packing staff can handle.

In order to exploit the sorting machine the row has to operate at an optimal capacity *(Figure 5),* but there cannot be double fruit at one measuring point. The movement of the roller carriers also ensures that, as the excess fruit drop-down at the side of the transport line and a belt delivers it back to the starting point of the line for repeated measurements. The roller carriers pass over an electronic grading scale. Two load cells per lane then gather weight information from each weigh point and process approximately 250 readings in less than 1/10th of a second for each fruit. Unique mathematical algorithms are an important but hidden part of the electronics that provide high precision.

Fig. 1: Loading the machine

Fig. 2: Manual selection

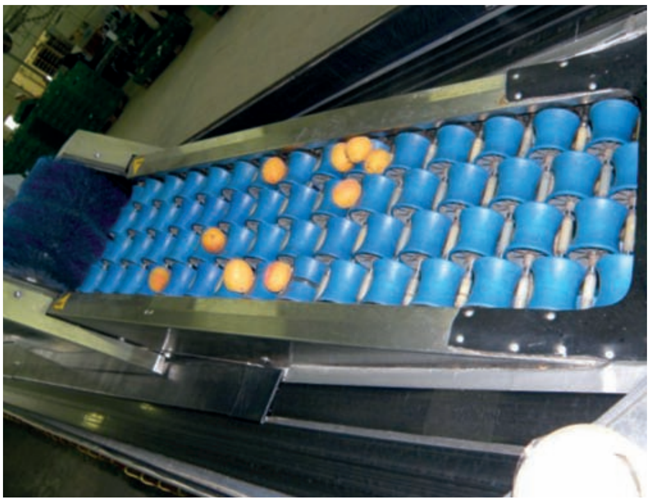

Fig. 3: Multi-line roller feeder

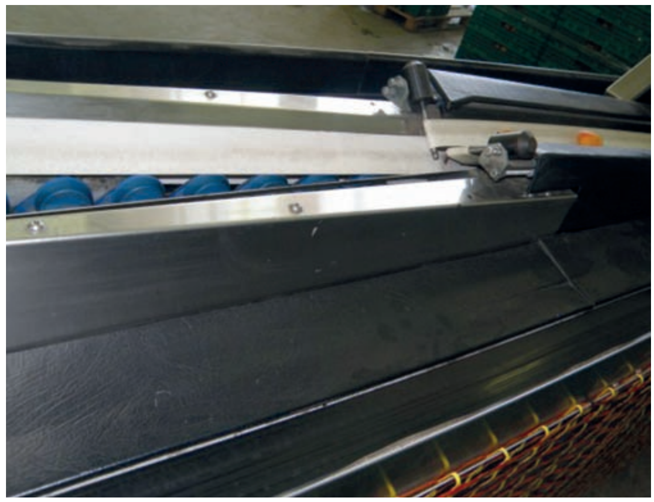

Fig. 4: Classifying belt

Fig. 5: Grading carriers line

Fig. 6: Three-line grading machine with one-side conveyor belt

Fig. 7: One-line machine with bilateral round table output

Fig. 8: Pack placed in plastic crates

Fig. 9: 1 kg fruit in a plastic box

Fig. 10: 2.3 kg fruit in a carton box

The machines are controlled by a computer. The speed, the weight categories and the output point of each category are adjustable.

The output can be at one or both sides of the machine and the packing can take place from the round tables or from the conveyor belt *(Fig. 6 and 7)* manually. The kerning is carried out using a balance. The customer demand determines how the fruit is presented:

- 5 kg bulk packaging in a timber bin (export), by 5 mm size-category;
- M10-type crates of 10 kg (domestic), by 5 mm size-category;
- In lines in a paper box;
- In lines in plastic crates *(Figure 8);*
- 1 kg in cardboard boxes;
- 1 kg in plastic box *(Figure 9);*
- 10×1 kg in carton box;
- 10×1 kg collapsible plastic crates;
- 2.3 kg in a carton box *(Figure 10).*

A Sorma-type net bagger is available for packaging the 1 kg units *(Figure 11).*

Fig. 11: Net bagger for 1 kg boxes

A template is used to adjust the weight categories *(Figure 12)*. The weight categories are determined by the size defined by the template and a suitable correlation. The following diameter categories are used when categorizing the fruit:

- 30–35 mm *C*
- 35–40 mm *B*
- 40–45 mm *A*
- 45–50 mm *AA*
- 50–55 mm AAA
- 55–60 mm *AAAA*

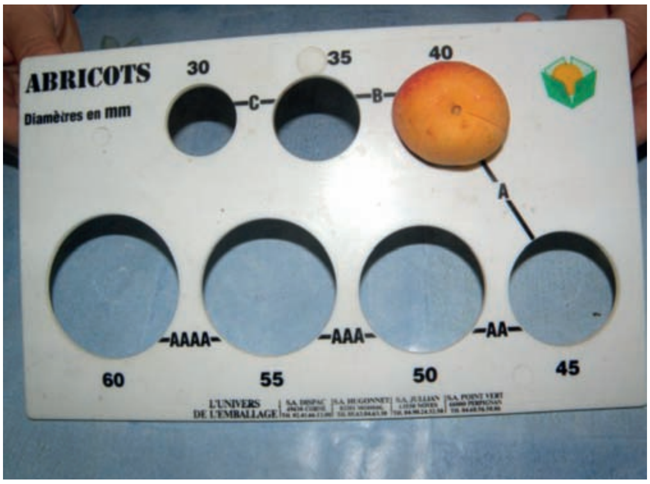

Fig. 12: Template for size category assignments

Table 1. Characteristics of Hungarian apricot

Size categories	40+	45+	50+
Width (mm)			
Minimum	36,91	43,42	47,07
Maximum	50,12	50,49	54,54
Expected value	42,51	47,05	50,64
Standard deviation	2,94	1,78	1,79
Thickness (mm)			
Minimum	34,75	38,92	41,84
Maximum	46,35	46,42	50,67
Expected value	38,96	43,02	46,84
Standard deviation	2,78	1,86	1,99
Height (mm)			
Minimum	36,29	41,79	45,04
Maximum	47,18	49,82	54,66
Expected value	41,16	45,96	49,68
Standard deviation	2,75	2,01	2,26
Weight (g)			
Minimum	27,40	42,40	51,20
Maximum	57,30	57,30	75,80
Expected value	37,58	49,83	63,05
Standard deviation	7,66	4,41	5,72

Results

The results of our examinations are summarized in tables and shown in figures by cultivars.

Hungarian apricot

This cultivar was sorted into three fractions A, AA and AAA. The results of the measurements are given in *Table 1.*

Since the determination of the weight categories is based on the width values of the fruit, taking into account an appropriate formula, our analysis was also performed according to the width values.

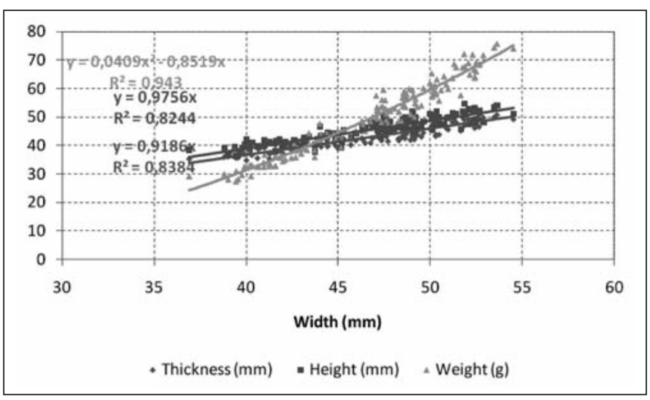

Fig. 13: The connection of the measured data with the width for Hungarian apricot

From the measured data (3 × 50), we present the change of the width in the function of the mass, thickness and height values *(Figure 13)*.

There is a close, second-degree correlation ($R^2 = 0.943$) between the width and weight. The thickness and height change linearly with the increase of the width, almost the same way. With the width-to-weight relationship the limit weight values to the category can be calculated *(Figure 14)*.

The standard deviation of the weight values (4.41 to 7.66) is acceptable, which shows a good shape fidelity. The standard deviation of the width values (1.78 to 2.94) is good, which indicates the good sorting accuracy of the machine.

The distribution of values for each width category can be also studied with graphs *(Figure 14)*.

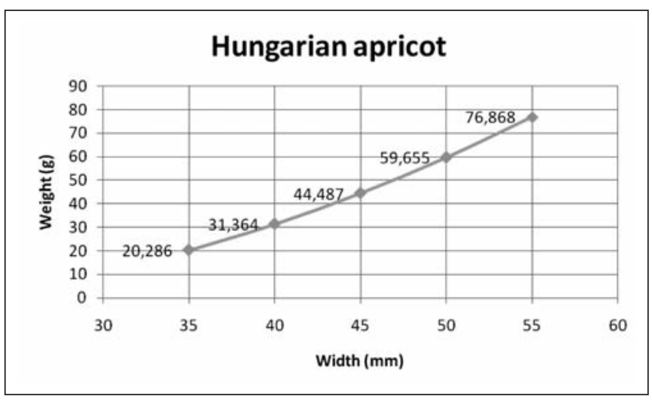

Fig. 14: Weight values calculated from the width-weight formula

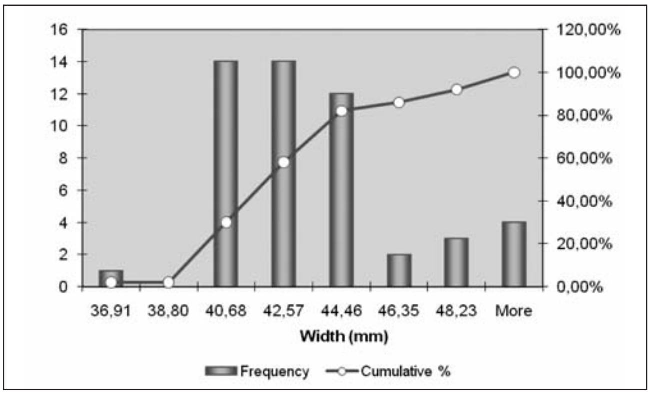

Fig. 15: Distribution of the width values of category A of Hungarian apricot

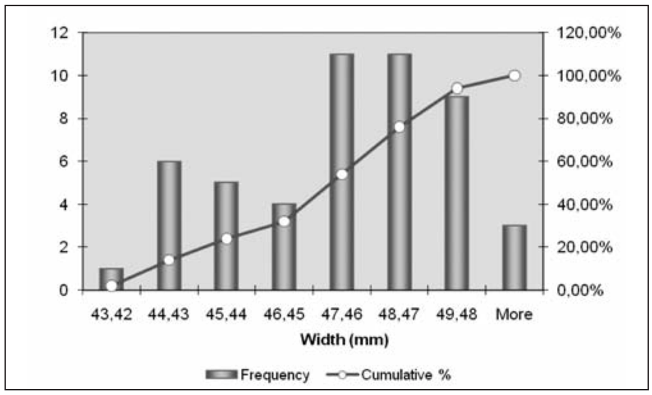

Fig. 16: Distribution of the width values of category AA of Hungarian apricot

The distribution of the width values of category *A* (40–45 mm) is shown in *Figure 15.*

The figure shows that the smallest apricot is 3 mm smaller than the lower limit for the category. 80% of the fruits is within the size category. The standard deviation (2.94) is acceptable.

The smallest width value of *AA* category (45–50 mm) remained slightly below the lower limit for the category *(Figure 16).* The maximum value is slightly above the upper limit of class size. The average value is within the boundaries of the category which shows the good selection of category limits.

The standard deviation value (1.78) is favourable. 92% of fruits are between the boundaries of the category.

The smallest width value of *AAA* category (50–55 mm) was 3 mm below the lower limit for the category *(Figure 17).* The maximum and the average value are within the boundaries of the category. The standard deviation value (1.79) is favourable, so the sorting accuracy of the machine appeared to be good. 72% of fruits are between the boundaries of the category, so the selection of category limits was not appropriate.

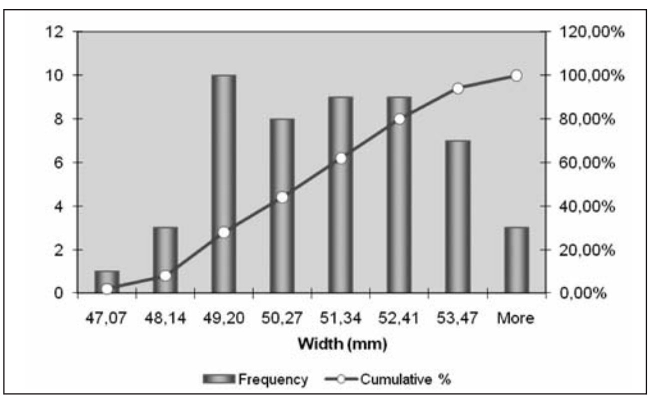

Fig. 17: Distribution of the width values of category AAA of Hungarian apricot

Jumbo Cot

This cultivar was sorted into four fractions *B*, *A, AA* and *AAA*. The results of the measurements are given in *Table 2.*

Table 2. Characteristics of Jumbo Cot

Size categories	35+	40+	45+	50+
Width (mm)				
Minimum	34,04	40,24	44,73	48,32
Maximum	43,77	49,00	50,76	56,18
Expected value	38,72	43,86	47,62	51,64
Standard deviation	1,59	1,94	1,43	1,96
Thickness (mm)				
Minimum	32,21	36,84	42,01	45,44
Maximum	42,24	49,06	48,14	58,52
Expected value	36,33	41,09	44,73	48,89
Standard deviation	1,56	2,10	1,57	2,05
Height (mm)				
Minimum	38,31	44,81	50,24	54,07
Maximum	51,69	57,36	59,33	63,17
Expected value	46,89	51,13	54,96	58,83
Standard deviation	2,33	2,34	1,81	2,09
Weight (g)				
Minimum	28,20	41,10	58,30	74,50
Maximum	54,10	68,20	79,90	95,40
Expected value	37,29	52,16	66,55	84,08
Standard deviation	3,78	5,12	4,96	5,88

From the measured data (4 × 50), we present the change of the width in the function of the weight, thickness and height values *(Figure 18).*

There is a close, second-degree correlation ($R^2 = 0.9516$) between the width and weight. The standard deviation of the weight values (3.78–5.88) is acceptable.

The width and height is changing linearly with the increase of the width, but in a different way. With the width-to-weight relationship the limit weight values to the category can be calculated *(Figure 19).*

The distribution of the width values were analyzed in detail and the distributions are presented in a chart.

The distribution of width values for category *B* (35-40 mm) is shown in *Figure 20.*

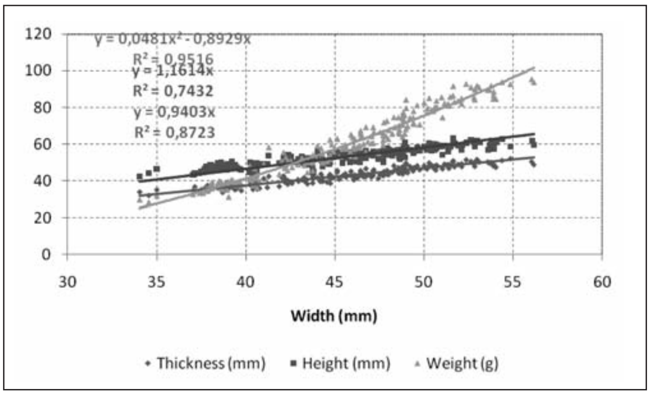

Fig.18. The connection of the measured data with the width for Jumbo Cot apricot

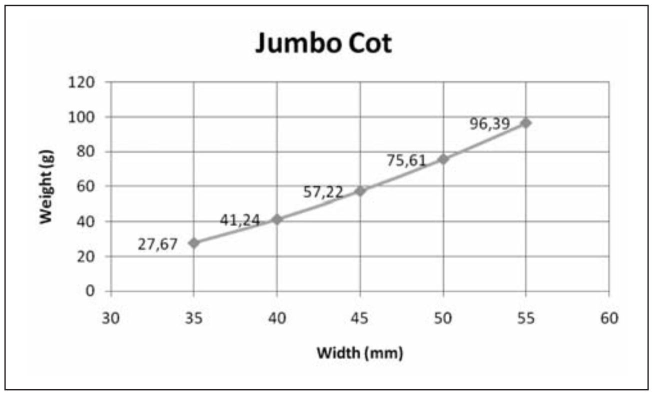

Fig. 19 Weight values calculated from the width-weight formula

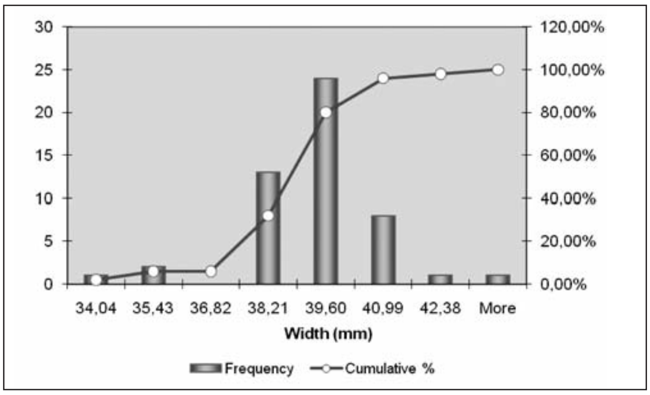

Fig. 20: Distribution of the width values of category B of Jumbo Cot

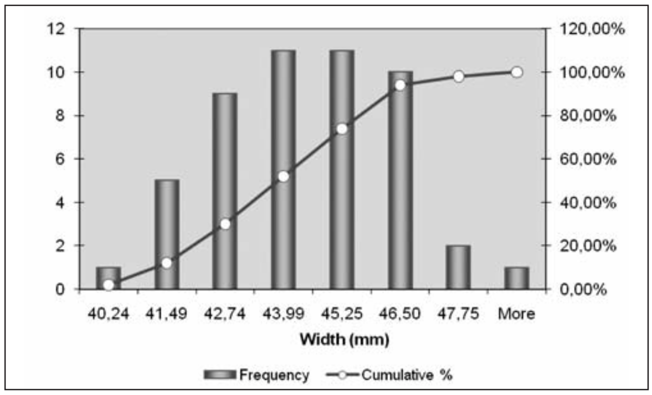

Fig. 21: Distribution of the width values of category A of Jumbo Cot

Only one apricot was below the minimum size of the category. The largest apricot was 4 mm above the upper limit of the category.

The average value was within the boundaries of the category. 94% of the fruits were within or close to the size category. The standard deviation (1.59) was favourable.

The smallest width value for category *A* (40–45 mm) remained within the category limits *(Figure 21),* however the largest value was 4 mm above the maximum value.

74% of the fruits were within the size categories, which shows that the selection of the category boundaries was not accurate enough. The standard deviation (1.94) was acceptable.

The smallest width value for category *AA* (45–50 mm) remained slightly below the minimum value, the largest value was a bit above the maximum value *(Figure 22),* and the average value remained between the boundaries of the category.

94% of the fruits were between the boundaries of the category, so the boundaries were chosen correctly. The standard deviation of this size category is favourable (1.43), which shows a good sorting accuracy.

The smallest width value for category *AAA* (50–55 mm) remained slightly below the minimum value *(Figure 23)*, the largest value was slightly above the maximum value and the average was between the category boundaries.

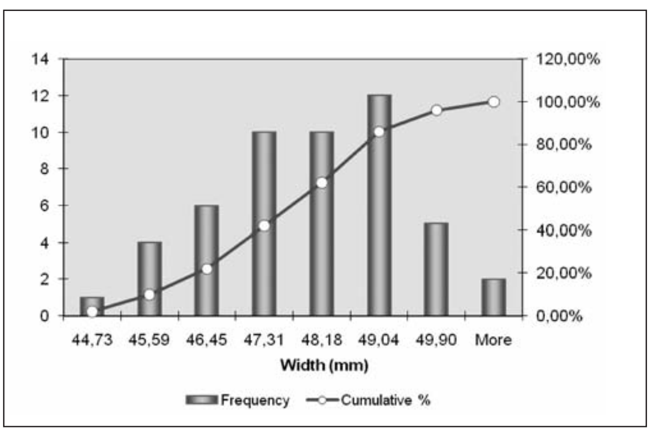

Fig. 22: Distribution of the width values of category AA of Jumbo Cot

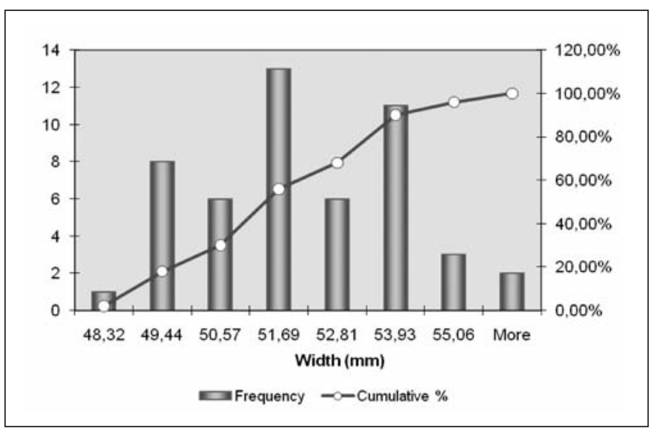

Fig. 23: Distribution of the width values of category AAA of Jumbo Cot

78% of the fruits were between the boundaries of the category, so the boundaries were chosen correctly. The standard deviation of this size category is favourable (1.96).

Bergarouge

This cultivar was sorted into three categories, *B, A* and *AA*. The measuring results are summarized in *Table 3.*

Table 3. Characteristics of Bergerouge apricot cultivar

Size categories	35+	40+	45+
Width (mm)			
Minimum	30,37	39,64	37,05
Maximum	45,58	46,08	50,84
Expected value	40,30	43,62	45,71
Standard deviation	2,69	1,56	2,69
Thickness (mm)			
Minimum	32,58	37,86	35,85
Maximum	43,50	43,50	54,02
Expected value	38,97	41,34	43,34
Standard deviation	2,05	1,27	2,93
Height (mm)			
Minimum	35,31	38,53	37,02
Maximum	44,51	46,44	52,73
Expected value	40,10	42,94	46,43
Standard deviation	2,40	1,70	2,84
Weight (g)			
Minimum	20,90	35,60	27,90
Maximum	47,50	48,30	71,20
Expected value	36,43	43,15	50,29
Standard deviation	5,59	3,51	7,84

From the measured data (3 × 50) we present the change of the width in the function of the weight, thickness and height values *(Figure 24).*

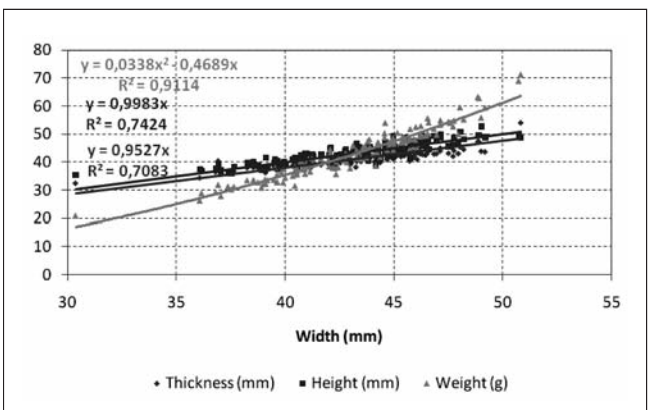

Fig. 24: The connection of the measured data with the width for Bergerouge apricot

There is a close, second-degree correlation ($R^2 = 0.9114$) between the width and weight.

The standard deviation of weight values (3.51–7.84) is acceptable. The thickness and height is changing linearly with the increase of the width. With the width-to-weight relationship the limit weight values to the category can be calculated *(Figure 25).* The distribution of the width values for each category is presented in the following diagram.

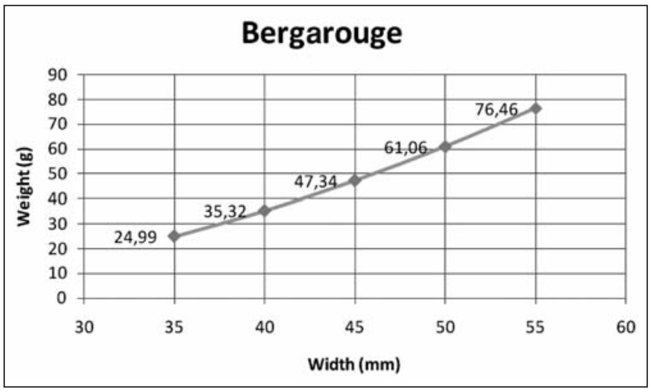

Fig. 25: Weight values calculated from the width-weight formula

The smallest value for category *B* (35–40 mm) was below the minimum value. The largest value was above the maximum value of the next category. The average was also above the maximum of the category. 24% of the fruits were between the category boundaries, which indicate a faulty machine setting. The standard deviation was 2.69. The distribution of the width values for category *B* is shown in *Figure 26.*

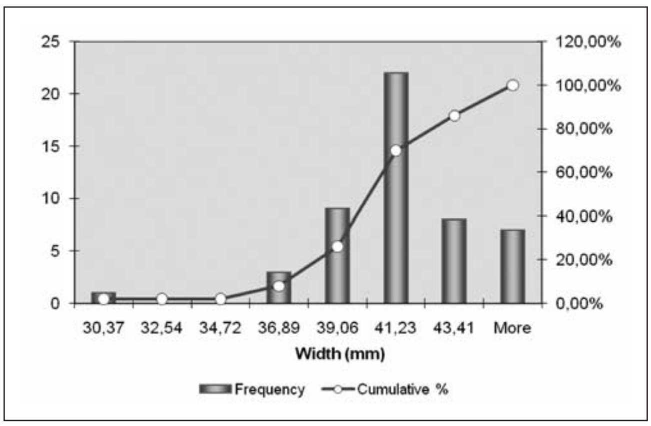

Fig. 26: Distribution of the width values of category B of Bergerouge

The smallest value for category *A* (40-45 mm) was below the minimum of the category *(Figure 27).*

The largest value was slightly above the category maximum. The average was within the category boundaries. 82% of the fruits were between the category boundaries. The standard deviation (1.56) was favourable.

The smallest width value for category *AA* (45–50) was significantly below the lower category limit *(Figure 28).* The largest value was slightly below the category maximum, while the average was between the category boundaries. 88%

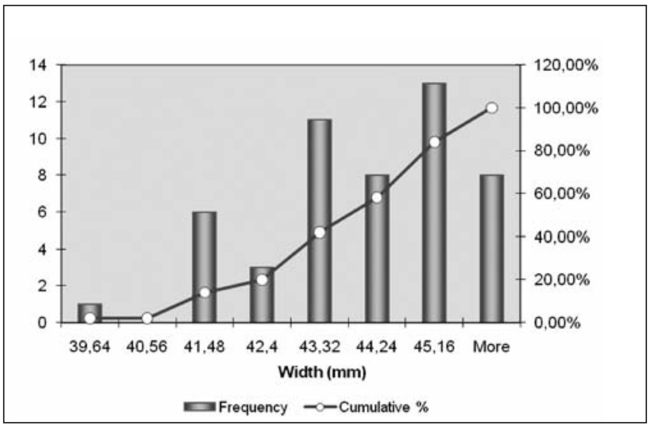

Fig. 27: Distribution of the width values of category A of Bergarouge

of the fruits were between the category boundaries, which show that they were chosen correctly.

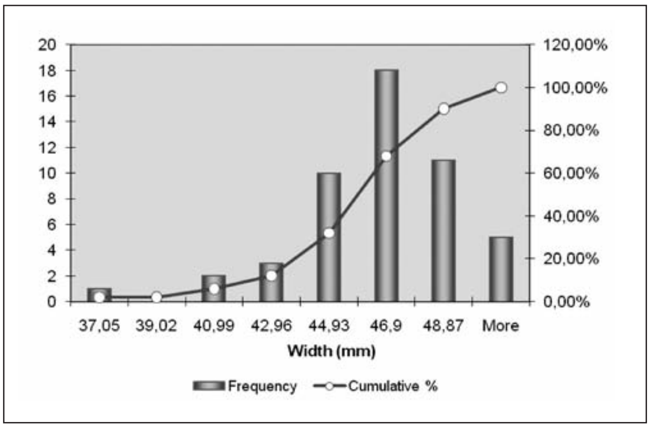

Fig. 28: Distribution of the width values of AA of Bergarouge

The standard deviation in category *AA* was acceptable (2.69).

Bergeron

This cultivar was sorted into three categories, *B, AA* and *AAA*. There was not available sample from size category *A*. The measuring results are summarized in *Table 4.*

From the measured data (3 × 50) we present the change of the width in the function of the weight, thickness and height values *(Figure 29).*

There is a close, second-degree correlation (R^2 = 0.9745) between the width and weight.

The mass variance is significant (6.56 to 10.64), which can be explained by shape errors.

The thickness and the height changed almost equally, linearly with the increase of the width.

With the width-to-weight relationship the limit weight values to the category can be calculated *(Figure 30).*

The smallest value in category B (35–40 mm) was slightly below the minimum of the category, while the largest value was above the maximum of the next size category. The medium value was within the category boundaries. Only 74% of the fruits was between the category boundaries, which shows sorting inaccuracy. The value of standard deviation (3.28) enhances that.

The smallest value in category B (35–40 mm) was slightly below the minimum of the category, while the largest value was above the maximum of the next size category.

Table 4. Characteristics of Bergeron apricot cultivar

Size categories	35+	45+	50+
Width (mm)			
Minimum	34,54	38,23	48,36
Maximum	47,52	49,67	61,76
Expected value	38,98	45,23	55,67
Standard deviation	3,28	2,48	2,78
Thickness (mm)			
Minimum	32,71	37,16	48,22
Maximum	46,40	47,20	59,92
Expected value	37,44	43,60	53,31
Standard deviation	3,36	2,11	2,61
Height (mm)			
Minimum	35,60	41,26	50,08
Maximum	50,35	52,20	61,26
Expected value	41,37	47,70	56,18
Standard deviation	3,99	2,20	2,50
Weight (g)			
Minimum	25,10	36,60	66,90
Maximum	63,20	65,20	122,10
Expected value	34,82	53,79	93,28
Standard deviation	10,19	6,56	10,64

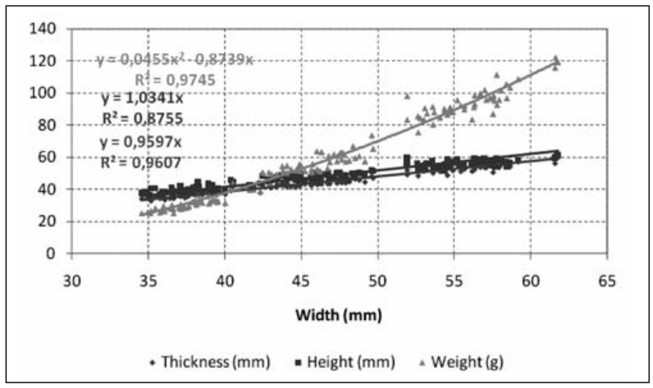

Fig. 29: The connection of the measured data with the width for Bergeron apricot

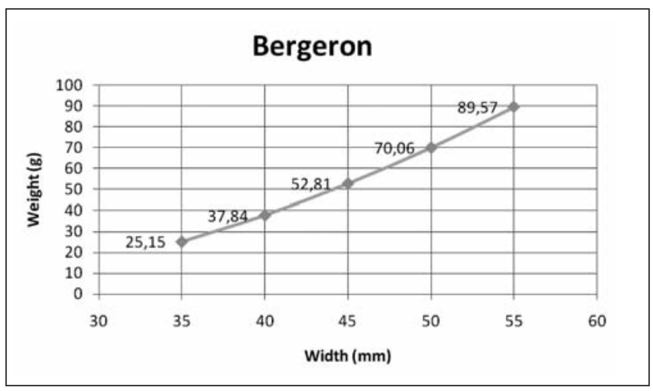

Fig. 30: Weight values calculated from the width-weight formula

The medium value was within the category boundaries. Only 74% of the fruits was between the category boundaries, which shows sorting inaccuracy. The value of standard deviation (3.28) enhances that.

The distribution of width values of category *B* is shown in *Figure 31.*

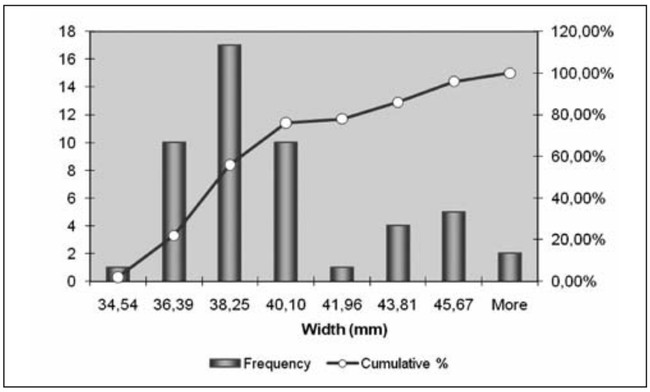

Fig. 31: Distribution of width values of category B of Bergeron apricot

The smallest width value of category *AA* (45–50 mm) was significantly below the minimum value *(Figure 32).* The largest and the average values remained within the category boundaries.

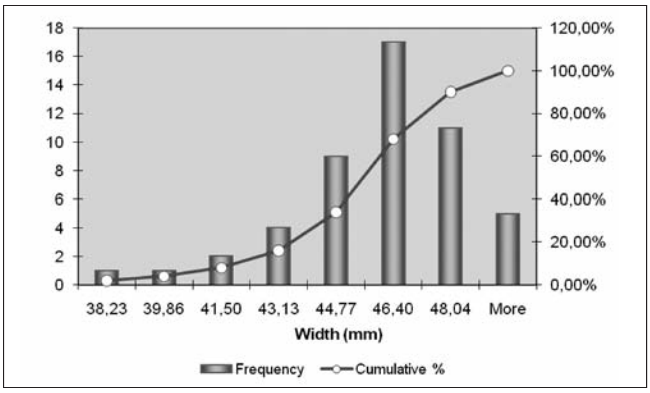

Fig. 32: Distribution of width values of category AA of Bergeron apricot

84% of the fruits were between the category boundaries, which means that they were selected correctly. The standard deviation (2.48) is also acceptable.

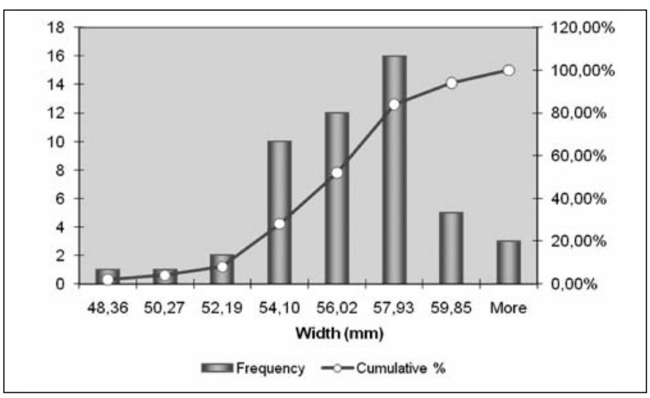

Fig. 33: Distribution of width values of category AAA of Bergeron apricot

The smallest width value of category *AAA* (50-55 mm) was below the minimum value *(Figure 33).*

Both, the largest and the average values were above the maximum value, and only 26% of the fruits were between the category boundaries, which indicates their incorrect selection. The standard deviation (2.78) in this size category was acceptable.

Late Jumbo

This cultivar was sorted into three fractions, *B, A* and *AAA*. There was not available sample from size category *AA*. The measuring results are summarized in *Table 5.*

Table 5. Characteristics of Late Jumbo apricot cultivar

Size categories	35+	40+	50+
Width (mm)			
Minimum	32,72	38,65	49,48
Maximum	44,74	45,83	59,62
Expected value	39,42	42,12	55,82
Standard deviation	2,42	1,59	1,96
Thickness (mm)			
Minimum	29,96	36,90	46,79
Maximum	44,00	49,92	55,62
Expected value	35,99	40,39	51,22
Standard deviation	2,98	2,25	1,99
Height (mm)			
Minimum	40,85	43,60	53,70
Maximum	51,13	51,13	67,16
Expected value	46,71	47,09	60,78
Standard deviation	2,22	1,81	2,25
Weight (g)			
Minimum	22,20	38,50	71,40
Maximum	54,30	54,30	109,00
Expected value	36,91	46,39	96,68
Standard deviation	6,64	4,33	7,08

From the measured data (3×50) we present the change of the width in the function of the weight, thickness and height values *(Figure 34).* There is a close, second-degree correlation ($R^2 = 0.9793$) between the width and weight. The mass variance is normal (4.33–7.08).

The thickness and the height changed linearly, but in a different way with the increase of the width. The width-to-weight relationship is suitable to calculate the values of the weight size categories *(Figure 35).*

The smallest measured width was significantly below the minimum of the size category, while the largest value was close to the maximum of the next size category. The average was between the minimum and maximum values. The distribution of the width values of this size category is shown in *Figure 36.*

80% of the fruits remained within the category boundaries or close to them. The standard deviation was acceptable, 2.42.

The smallest width value for category *A* was significantly below the minimum value of this category *(Figure 37).*

The larges value only slightly exceeded the upper limit of the category. The standard deviation was acceptable, 1.59.

96% of the fruits were between the category boundaries, which proves the good selection of the category limits. The standard deviation was favourable, 1.96.

The smallest width value in category AAA was also significantly below the minimum value of this category *(Figure 38).* The largest value was substantially higher than

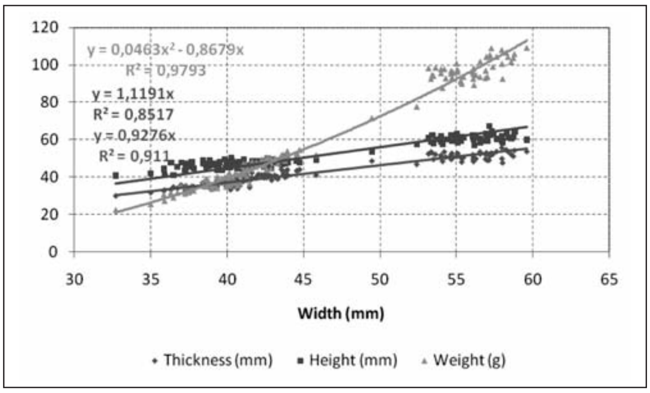

Fig. 34:The connection of the measured data with the width for Late Jumbo apricot

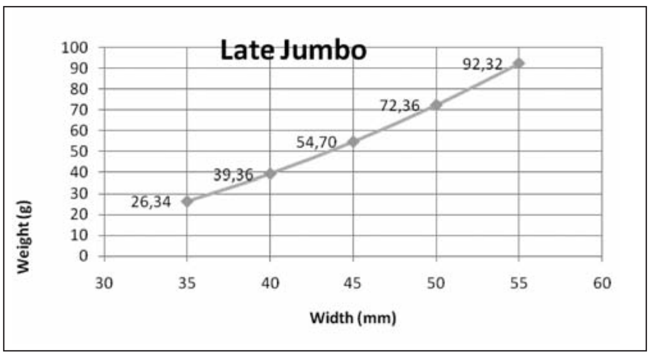

Fig. 35: Weight values calculated from the width-weight relationship

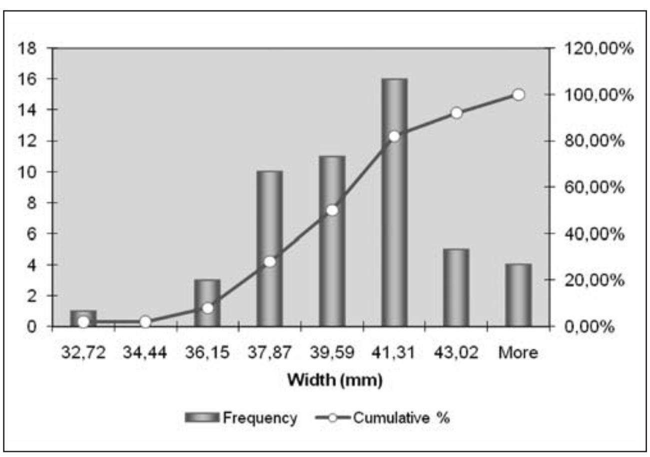

Fig. 36: Distribution of width values of category B of Late Jumbo apricot

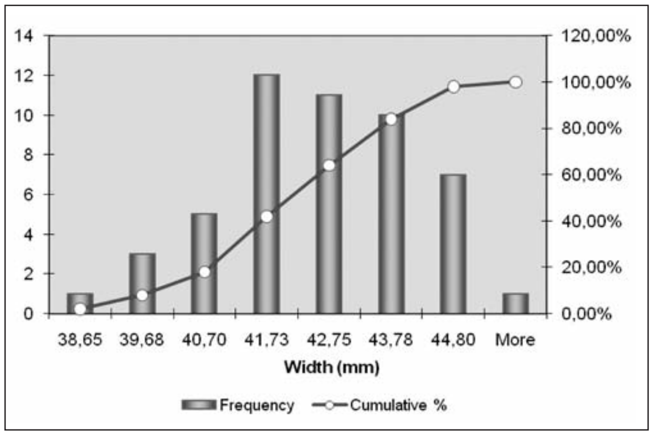

Fig. 37: Distribution of width values of category A of Late Jumbo apricot

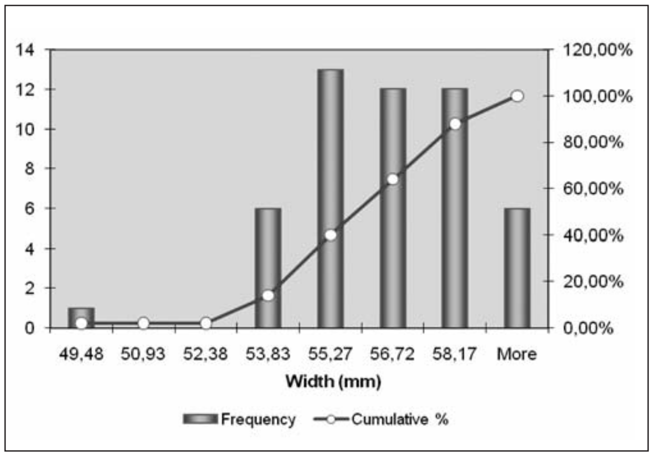

Fig. 38: Distribution of width values of category AAA of Late Jumbo apricot

the upper category limit. The average value was slightly above the maximum.

Only 38% of the fruits was between the category boundaries, which shows sorting inaccuracy. The standard deviation of width values of *AAA* category was favourable, 1.96.

Some operating characteristics connected to sorting

We highlight some features from data recorded during the packaging season *(Table 6).*

Table 6. Some operating characteristics connected to sorting

	Total loaded weight (kg)	Sorted (kg)	Immature (kg)	Industrial (kg)	Machine performance (t/h)
Hungarian apricot	1110	930	–	180	3,00
Jumbo Cot	224	158	50	16	2,84
Bergerouge	940	860	60	20	0,90–1,10
Bergeron	986	900	60	26	2,00
Late jumbo	3512	2690	616	206	2,50

Regarding the ratio of the total weight loaded on the sorting machine and the weight of fruits that were sorted from that amount, the best results were given with Bergerouge and Bergeron cultivars (91%). The same data for Hungarian apricot were 84%, for Late Jumbo 77% and for Jumbo Cot 70%.

There are significant differences in the performance of the machines when sorting different cultivars (3–1.1 t/h), which can be explained with the different shape characteristics of the different cultivars.

It is interesting to study the percentage of fruits in each size category *(Table 7).*

Table 7. Size distribution of some apricot cultivars

	C	B	A	AA	AAA	AAAA
Jumbo cot	1,2	19,6	46,8	27,8	3,1	1,2
Bergerouge	0	3	34	56	3	0
Bergeron	0,1	3,1	17,6	52,4	18,2	8,3

A significant part of the fruits got into *A* and *AA* category in the case of the three studied cultivars. These values are 75% for Jumbo Cot, 90% for Bergerouge and 70% for Bergeron.

Results

1. The width-weight relationship was determined for the listed apricot cultivars. With the help of these data the weight categories can be assigned from the width (diameter) of the fruit precisely. A quadratic function describes the relationship with different strength of correlation in the case of different cultivars (R^2 = 0.9114 to 0.9793).
2. We determined the standard deviation values of weight distribution for each cultivar (3.51–10.64).
3. We analysed the distribution and standard deviation of the width values by cultivars and size categories (1.43–3.28).
4. We determined the percentage of the fruits within the size category limits for each cultivars and size categories. A correct machine setting resulted in a good, 92–96% ratio, while the faulty setting caused a week 24–26%. Regardless of the extremely bad selection of category limits, the average is 84%.
5. We provide data of the percentage of the fruits that were sorted from the total weight loaded on the machine. The results were 91% for Bergerouge és a Bergeron, 84% for Hungarian apricot, 77% for Late Jumbo and 70% for Jumbo Cot. Of course, this is about the state of maturity, as immature and industry ratio depend on that.
6. Data are available of the performance of the sorting machines (1.1–3 t/h) for each examined cultivars. The differences can be explained with the different shape characteristics of the different cultivars
7. The percentage of fruits is given in the size categories with three cultivars. In *A* and *AA* category was 90% of Bergerouge, 75% of Jombo Cot and 70% of Bergeron apricots.
8. It can be stated that if the assignment of the category boundaries is correct, 90% of the fruits will remain within the category boundaries and the sorting accuracy of the machine will be appropriate.

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References

Ancza, E., Csizmazia, Z., Polyák, N. I., Farkas, E., Nyéki, J., Szabó, Z. (2011). Work Quality Assessment of a Cherry Sorting Machine. International Journal of Horticultural Science, 17. (1–2): 57–62.

Polyák, N.I., Csizmazia, Z. (2003): Phisical Properties of Seeds of Vegetables. Hungarian Agricultural Engineering, 16: 35–37.

Polyák, N.I., Csizmazia, Z., Ancza, E. (2010). Some physical properties of sweet cherries. International Journal of Horticultural Science, 16 (1): 63–70.

Polyák, N. I., Csizmazia, Z., Vaszil, B., Ancza, E. (2011). Sampling Experience in a Cherry Plantation. International Journal of Horticultural Science, 17. (1–2): 21–28.