Int. Agrophysics, 2001, 15, 13-18

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Some physical and nutritional quality parameters of storage apple

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Received November 22, 1999; accepted October 18, 2000

A b s t r a c t. The authors developed a sorting line for sizing and sorting of apples. Different size apples were taken from storage and were sorted to improve fruit quality. Apples from the outlets of sorter were carefully analysed in terms of size, weight and colour to assign a fruit quality index. The taste of fruit and some nutritional values (reducing sugar, L-ascorbic acid) were determined to achieve a final fruit quality index.

K e y w o r d s: apple, storage, quality parameters

INTRODUCTION

Apple production reaches about 40 millions tons annually, in fourth place after grapes, citrus fruits and bananas. Major producers of apples are European countries such as France, Italy, Poland and Hungary [8,9]. European production of apples has exceeded demand for the last two or more years. Poland, being situated at the entry to eastern markets is in a strong position to serve the European apple industry. Poland produces many apple, however, most are sold as industrial apples or used for concentrate. About 15–35% of Poland's apples are suitable for consumption. Disappointingly, half the production of apples in Poland did not meet quality requirements for the consumer market and was sent for industrial processing. Poland must improve the quality of their apples in order to become competitive in the consumer market place.

McClure [21] noted that a new trend in quality control took place shortly after World War II. Prior to WWII, adequate production of fruits and vegetables made it possible to "send the good to market and throw away the bad". In recent years this production philosophy changed. Producers can no longer afford to toss out any portion of a harvest. Every bit of the harvest must be used in order to achieve what McClure called maximum food potential. However, achieving maximum food potential requires making quality measurements at, or close to, the time of harvest as possible [21]. By doing so, the good can be sent to the fresh market, the green and the over-ripe can be set aside for processing into food products.

Quality factors for fresh fruit and vegetables were defined by Kader [18] as: hygiene and quarantine factors (parasites larvae, pupae, natural toxicants, contaminants, spray residues, heavy metals etc.), cosmetic appearance (size, weight, volume, dimensions, shape, regularity, surface texture, smoothness, waxiness, gloss, colour, uniformity, intensity, spectral, physical defects, splits, cuts, dents, bruises), texture (firmness, hardness/softness, crispness, mealiness-grittiness, fibrousness toughness), and flavour factors (sweetness, sourness, astringency, bitterness, aroma, off-flavours, off-odours) and nutritional (dietary fibre, cancer inhibitors, carbohydrates proteins, lipids, vitamins, minerals). One of the basic conditions for improvement of quality is proper sorting and handling of the apples for market [1–4,7,15,23,28,38]. For example, sorting-for-quality on harvest machines would go a long way towards maximizing food potential. Separating ripe from the over ripe would allow the "good" food (having adequate shelf life) to be shipped to fresh market while the less desirable, the green and the over ripe fraction, could be send to a processing plant where quality could be enhanced by appropriate bioprocessing techniques [21].

Most apples can be roughly divided into three classes: dessert, table and industrial apples. Apples grown for consumption should be crisp, have a lot of juice, taste good and have nice smell and have an appealing colour. Colour

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and size of apples are two very important quality criteria for commercial apples [2,6,32–35].

In Poland apples are sorted into three groups in order to meet certain norms. Large fruits like Lobo, Boskoop, Red Delicious, Melrose, Jonagold and Gloster should be at least 7 cm diameter in order to be classified "Extra" (i.e., the best quality). Dividing other apples in classes 6.5, 6.0 cm, etc. (i.e., with a 0.5 cm spread in each class) enhances marketing and bring a higher price. Alternatively, other classifications should be divide into 1.0 cm ranges: The first assortment would be apples with a diameter greater than 6.0 cm. The second assortment would be apples greater than 5.5 cm. Finally, apples smaller then 4.5 cm in diameter would be classified as an industrial.

Apples produced on Polish farm's apples are usually sorted by hand [10,28]. Producers normally have sorting lines connected to packaging equipment. These lines have box filling units, bag filling units, tray-packing units, i.e., all the equipment necessary for the preparation of fruits according to orders, a process that guarantees the highest prices possible [1–4,10–16]. These lines are very expensive. Not all growers can afford them, especially when they are not sure that future production and fruit prices will enable them to pay the cost of equipment and production.

This study was one part of more extensive project designed to study the relationship of physical properties (such as firmness) of fruit to quality. Objectives of this research were four:

1) to evaluate and predict the effect of fruit sorting in post-harvest handling;

2) to study the influence of a sorting on such fruit parameters as size, shape, weight and mechanical damage of several cultivars;

3) to study the relationship of apple colour to subjective consumer quality;

4) to determine nutritional value of apple, certify final quality of fruits after storage.

MATERIALS AND METHODS

Nine cultivars (Cortland, Gloster, Idared, Jonagold, Priam, Red Elstar, Holyday, McIntosh and Spartan) were studied. These cultivars are discussed in another paper [12] with reference to fruit firmness. The Cascade M–625 sorting line (Sipma s.a. Lublin) was used to sort the fruit. The M–625 was designed to sort spherically-shaped fruits, such as, apples, oranges, grape fruits, lemons, pears, tomatoes, kiwi fruits and plums. The sorter was modified in order to minimise damage and bruising. The fruits were rolled on a moving belt in the front of different gates openings in order achieve sizing. The gates were adjusted to size fruit in steps of 5 mm each. All fruits from the outlets of the sorting line were weight and the diameter was measured with an accuracy of 0.01 mm. Mechanical damage and bruising of apples were recorded to determine the effect of sorting on fruit quality and make assignments according to market acceptability and storage.

Colour and size of apple were found to be the most important criteria of all the parameters established by comsumers. Five cultivars (Cortland, Idared, Priam, Elstar, Holyday, and Spartan apple) were taken from storage to determine colour (L*a*b* system) in terms of hue, saturation and brightness [6,17]. Seven other cultivars (Delikates, James Grieve, Freedom, Liberty, Empire, Koksa Pomarańczowa, and Rubinowe Duhi) were measured for colour. The colour of each apple was measured at six points around the stem-axis.

Nutrition of apples, while not always apparent in the marketplace, is of utmost concern to consumers, especially for apples that remain in storage for a long time. Reducing sugars and L-ascorbic acid (parameter related to taste) were measured in seven (Gloster, Idared, Jonagold, Red Elstar, Gala, Melrose, and (Šampion) of the twelve cultivars named in previous paper [13] after 20 weeks and 35 weeks of storage. Reducing sugars were determined according to procedures established by other researchers [5,12,22,25].

RESULTS

Size, shape and weight

For all cultivars studied, a linear relationship existed between the maximum and minimum size of fruit. However, only the results of the cultivar Priam is presented in this paper. The relationship between maximum and minimum size of Priam apples is shown in Fig. 1b. This implies that mid-stem-axis cros-section of the Priam apple tends to be nearly circular in shape. However, correlation coefficient (R=0.70) between maximum diameter (D_{max}) and axis height (h) was low, indicating shape irregularities in the vertical cross-section plane (Fig. 1a). Low correlation was observed between axis height (h) and diameter of fruit for other studied apples. The circular shape of apples (viewed from the top) was found to be almost a perfect circle (R = 0.92 to 0.97 for all cultivars). As expected for the cultivar Elstar, there was a high correlation (R = 0.98) between weight and fruit diameter (Fig. 1c).

The large variation in fruit size (diameter as well as height) indicates that apples should be sorted to improve quality. For example, Gloster apples are large ranging in diameters from 63.3 to 88.6 mm. Weight of these apples ranges from 101 to 256 g, respectively. Most of them should be classified as Extra (or best quality). In comparison, Holyday apples (Fig. 1d) range in diameter from 43.3 to 73.8 mm and range in weight from 36 to 147 g. Very few of the larger ones are suitable for the Extra class. Since most of the Holyday apples are too small to be classified as Extra, the benefits gained by mechanical sorting may not warrant the expense. However, since the study shows a high correlation

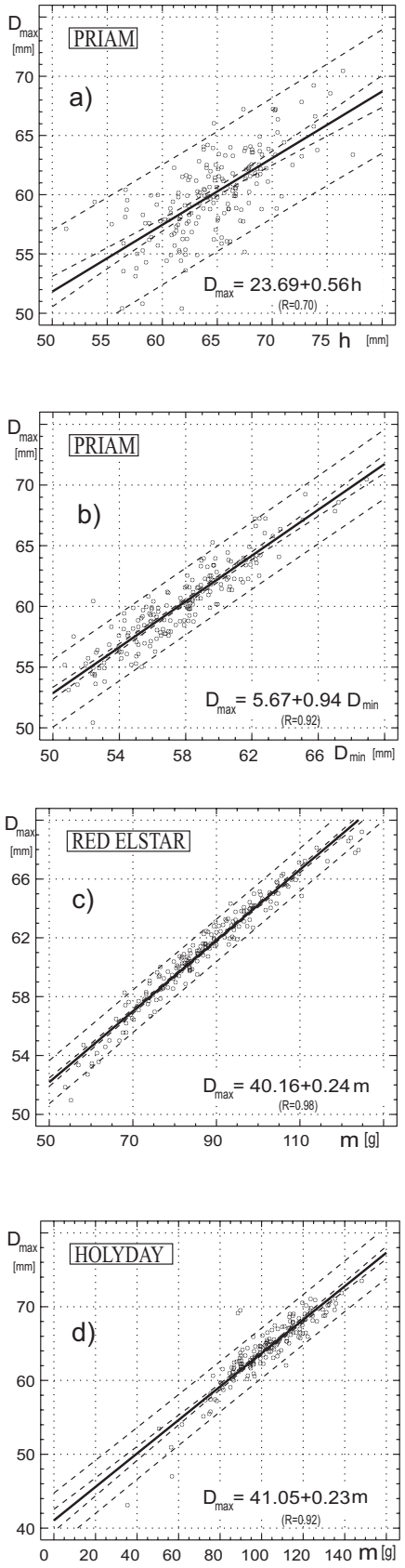

Fig. 1. Physical characteristics of apple size and weight.

between fruit size and weight, it seems likely that weight should be a major quality factor.

The effects of sorting Gloster and Holyday apples with the Cascade M–625 sorter are shown in Fig. 2. Gloster apples, being more spherical than the Holyday apple produced a correlation of R=0.907 while the Holyday apple, having a more irregular shape produced a correlation of R=0.705. This seems to show that the Cascade sorter is not particularly effective for sorting irreguarly shaped apples. Again, since most of the Holyday apples are too small to be classed as Extra, sorting with the Cascade sorter should be avoided. Sorting Holyday apples should be done by hand.

Colour

The brightness index (L*) of Cortland, Idared, Priam, Elstar, Holyday, Spartan, Delikates, James Grieve, Freedom, Liberty, Empire, Koksa Pomarańczowa, and Rubinowe Duhi apples is shown in Fig. 3. Note that the L* data ranged from 30 to 70 for this experiment. Interestingly, the James Grieve cultivar was the only fruit that produced a nearly constant L*. The Spartan apples had dark–purple skin and, therefore, gave low L* values.

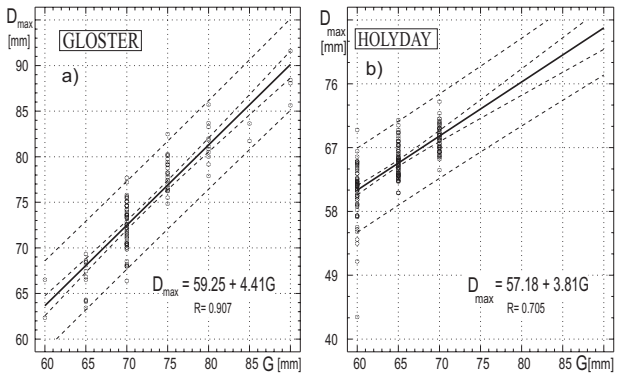

Fig. 2. The effect of fruit grading with Cascade sorter.

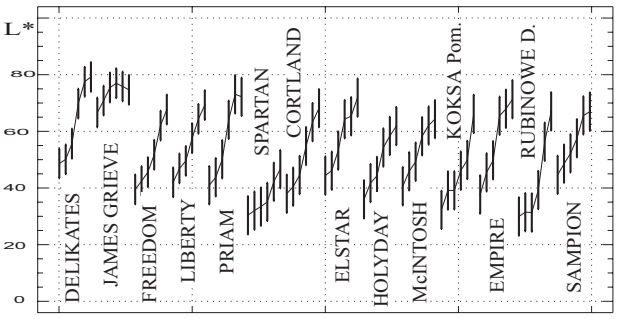

Fig. 3. The brightness parameter L* of apple colour.

The saturation of red colour, presented in Fig. 4 as the index of chromaticity or a*, range from –5 to 40 for the cultivars tested. James Grieve apples, having no red colour, gave a* values very near to zero. Empire, Cortland, Delikates, and Freedom apples had a slight hue of green. Spartan apples were saturated with red colour that passed through the purple. Mature apples exhibited no green colour. Any significance minus a* values indicated the absence of green colour on the surface of apples.

James Grieve apples were significantly different from Spartan apples in terms of a*. The values of the index b* (Fig. 5) for James Graive apples were close to 60 indicating that the skin of the Grieve apples were practically pure yellow in colour. All parameters of colour obtained in this study shows that L*a*b* indexes for Freedom, Liberty, Holyday, and McIntosh apples were not significantly different. Nonetheless, determination of fruit quality based on the L*a*b* system should be useful for marketing since it would more clearly difine consumer colour preferences.

Nutritional value

The average reducing-sugar content of all apples, after 20 weeks of storage was found to be 1.07% (see Fig. 6) Further storage increased the reducing sugar content of all apples. After 35 weeks of storage the average reducing sugar content across all apples was 2.66 %. However, the increase of reducing sugar content was different for each cultivar. The sweetest apples after 35 weeks of storage were (ampion (4.08 %) and Gala (4.01 %). The other apples ranged in sugar content from 2.14 % to 2.89 %. Gloster and Melrose apples were the least sweet of all.

The L-ascorbic acid, strongly related to vitamin C, was measured in mg per 100 g of apple tissue (excluding the peeling). The average L-ascorbic acid contents of the various cultivars obtained after 20 weeks (black dots) and 35 weeks (circle) of storage are plotted in Fig. 7. Idared and Red Elstar apples had the highest average L-ascorbic acid content of all the cultivars (5.36 mg and 4.44 mg/100 g, respectively). L-ascorbic acid content of Melrose apples was about the same as for Šampion apples (ranging from 3.25 to 3.32 mg/100 g. Gala (1.54 mg), Gloster (1.68 mg) and Jonagold (1.35 mg) apples had low levels of L-ascorbic acid. After 35 weeks of storage L-ascorbic acid content definitely decreased more than four times for Idared and Red Elstar apples. The L-ascorbic acid contents in Gloster apples (1.68 mg/100 g) remained stable during storage.

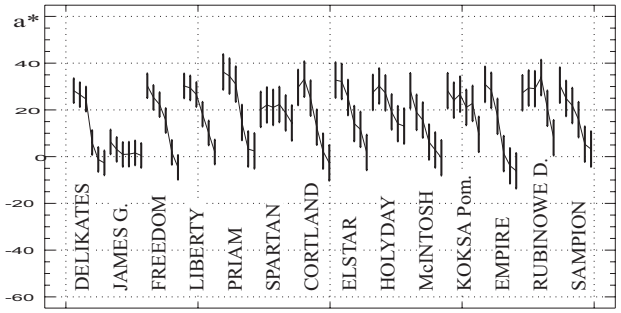

Fig. 4. The chromaticity parameter a* of apple colour.

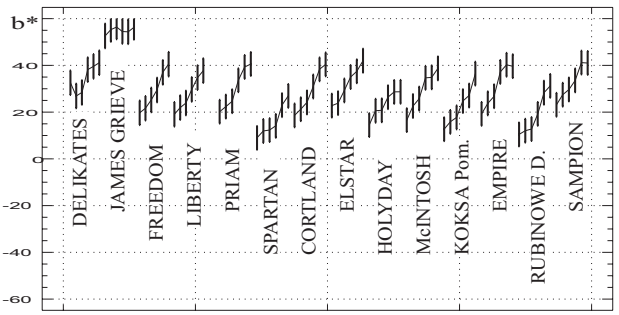

Fig. 5. The chromaticity parameter b* of apple colour.

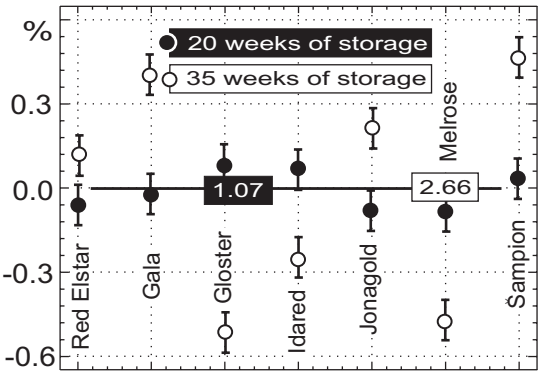

Fig. 6. The sugar contents in the apple flesh after fruit storage.

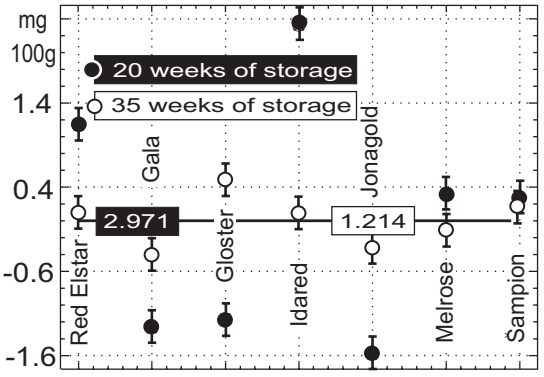

Fig. 7. The L-ascorbic acid content in apple tissue after fruit storage.

DISCUSSION

Firstly, quality standards are affected by international and cultural preferences. Secondly, standards can be affected by cultural changes or by strong marketing in the media. Quality standards may involve appearance, feel, taste, consistency, handling characteristics, and ability to retain properties for long periods of time [18]. At harvest, crispness, content of juice, good taste and aroma, nice colouring of the skin are consumer favorites. Kader [18] indicated that major quality factors include cosmetic appearance, texture, flavour, nutrition, hygiene and quarantine factors.

When apples are grown, it is possible to eliminate the negative influence of some hygiene and quarantine factors such as parasite's larvae, pupae, natural toxicants, contaminants, spray residues, heavy metals, etc., affecting fruit quality. After harvest, cosmetic appearance seems to be the most important quality factor. However, numerous researchers have studied many other factors such as size, weight, volume, dimensions, shape, regularity, surface texture, smoothness, waxiness, gloss, colour, uniformity, intensity, spectral, and physical defects, splits, cuts, dents, and bruises [2,6,16,20,27,31,37], in order to improve quality. Preparing fruits and vegetables for the market by sorting on the basis of physical parameter of apples appears to be adequate for quality improvement [1–4,7,15,23, 28,38]. Various methods have been used to characterise apple shape that could help explain the preferred orientation for fruit in a given handling system. Whitelock, *et.al* [37] found that parameter ratios which describe elongation (h/D) were better predictors of apple rolling orientation than taper or symmetry. In this study, low correlation was observed between axis height (h) and diameter (D) of fruit for apples of most cultivars. A low correlation was also observed between h and D. Apples that were relatively irregular in the shape changed orientation during rolling, which caused the Cascade grader to do a poor job of grading in terms of weight and size (gate number). Apples with the axis close to the center of gravity tended to roll parallel to belt, allowing improved grading.

McClure's dream [21] was that the most important quality parameters must be determined in the field with real-time sensors. In addition he dreamed of hand-held instruments that would aid the farmer to make quick checks of maturity of fruit growing in the field. The authors have developed a simple elastometer form estimating maturity of fruit growing on a tree [12].

Mechanical grading methods for weighing and sizing are available for the apple industry. However, colour and texture must be taken into the consideration if true apple quality is to be recognised. Apples sorted by mechanical devices become damaged (skinned and bruised). Firmness, crispness, hardness/softness, mealiness-grittiness, fibrousness, and toughness are influenced by mechanical handling. Mechanical handling has a deleterious effect on apple firmness. Storage had significance influence on the mechanical properties estimated by the tests [12] used in this study. The elastic behaviour of fruit shown that fruit firmness decreased unequally for studied varieties after storage and the modulus of elasticity more distinctly show the slightly changes of apple firmness during the range of storage period. Most frequently studied parameter was firmness, therefore some results of mechanical properties conected with firmness were presented in previous papers [10–13].

Significantly changes of colour during fruit storage were observed only for bruise's apples [31]. Bruising does not break the skin of an apple, but influences its appearance. During the range of storage period the colour of apple skin is unchanging, however, as an important factor must be included in any consumer quality estimation.

For the market the apples of each variety can be roughly divided into dessert, table and industrial. Although, quality of desert apples based on appearance factors, the nutritional factors must be included in quality estimation of table apples, as well as for industrial processes.

The intake of C vitamin increased in the nutrition of European populations, while in Poland it is on similar level about 140 mg [8]. Therefore, the dearth of C vitamin in human nutrition should be substitute by the increase of fruit's consumption or the changes of food structure. The wide range of studied parameters allow to estimate some quality factors of horticulture products such as: size; weight, dimensions, shape, colour, water potential and mechanical characteristics. However, often nutritional values of fruits and vegetables decided final quality of food.

CONCLUSIONS

Sizing with a simple mechanical-type sorter improves apple quality. High correlation between the maximum size and weight of fruit prove that the weight could become a proper quality index for apples. Determination of fruit quality based on L*a*b* system colour should be useful for making decisions pertaining to the marketability of apples. The L*a*b* system, if probably integrated into a marketing plan, could improve apple quality and make consumers more aware of true quality factors. There are many different factors which can be included in any discussion of quality, however, it should be given appropriate care and attention for nutritional quality of fruit after storage.

REFERENCES

1. **Bellon V., Rabatel G., and Guizard C., 1992.** Automatic sorting of fruit: sensors for the future. Food Control, 49 – 54.
2. **Bennedsen B.S. and Nielsen H., 1997.** Size and shape measurement by acoustic reflection. 5th Int. Symp. on Fruit, Nut, and Vegetable Production Engineering, Davis, California, USA, S6(4):1–12,

3. **Brown G.K., Schulte-Pason N.L., Timm E.J., Burton C.L., and Marshall D.E., 1990.** Apple packaging line impact damage reduction. Applied Engineering in Agriculture, 6(6), 759–764,
4. **Chen P., 1996.** Quality evaluation technology of agricultural products. Proc. of ICAME'96, Seul, Korea, Vol., I, 171–190.
5. **Cho S.I., Bellon V., Eads T.M., Stroshine R.L., and Krutz G.W., 1991.** Sugar content measurement in fruit tissue using water peak suppression in high resolution 1H magnetic. J. Food Sci., 56 (4):1091–1094.
6. **Delwiche M.J. and Baumgardner R.A., 1985.** Ground color as a peach maturity index. J. Amer. Soc. Hort. Sci., 110, 53–57.
7. **Delwiche M.J., 1987.** Theory of fruit firmness sorting by impact forces, Trans. ASAE, 1160–1166, 1171.
8. **Dobrzańska A., 1995**. Changes in levels of nutrition and the structure of the Polish population in the years 1958–1990 on the basis of household budgets. Materia Medica Polona, 27(1),78.
9. **Dobrzańska A. and Tymolewska B., 1995.** The comparison of level and structure of nutrition of Austria and Poland in the years 1960–1990. 7th European Nutrition Conference Vienna, V, 24–28.
10. **Dobrzański, jr. B. and Rybczyński R., 1997.** Elasticity meter - apple fruit quality grading. Food Processing and Packing Technology, China Machine Press, 84–92.
11. **Dobrzański, jr. B. and Rybczyński R., 1997.** A new firmness meter for fruit quality grading. 5th Int. Symp. on Fruit, Nut, and Veg. Prod. Eng., Davis, 10 (2), 1–6.
12. **Dobrzański, jr. B., Rybczyński R., and Dobrzańska A., 1998.** Physical and nutritional properties of apple. Abstracts of XXV International Horticultural Congress, Brussels, PP 2/03/A–23, 358.
13. **Dobrzański, jr. B., Rybczyński R., and Gołacki K., 2000.** Quality parameter of storage apples as a firmness. Int. Agrophysics, 14, 149–157.
14. **Duprat F., Pietri E., Grotte M.G., and Studman C.J., 1995.** A multi-purpose firmness tester for fruits and vegetables. Journal of Computers and Electronics in Agriculture, 12, 211–223.
15. **Guyer D., Brook R., and Timm E., 1993.** Lighting systems for fruit and vegetable sorting. Bulletin AEIS–618, USDA, Michigan State University, East Lansing.
16. **Holt J.E. and Schoorl D., 1984.** A hard systems approach to the management of quality in apple distribution. Agricultural Systems, 13, 129 –142.
17. ISO, 1987. ISO 9000, 1987. Quality management systems. International Standards Organisation.
18. **Kader A.A., 1983.** Postharvest quality maintenance of fruits and vegetables in developing countries. Postharvest Physiology and Crop Production, Plenum, New York, 455– 470.
19. **Kawano S., 1994.** Present condition of nondestructive quality evaluation of fruits and vegetables in Japan. JARQ, 28, 212–216.
20. **Klein J.D., 1987.** Relationship of harvest date, storage conditions, and fruit characteristics to bruise susceptibility of apple. J. Am. Soc. Hort. Sci., 112, 1, 113–118,
21. **McClure W.F., 1995.** Biological measurements for the 21st century. Keynote paper at Agricultural and Biological Engineering Conference, "New Horizons, New Challenges", Newcastle, Session 3, 1–9.
22. **Miller G.L., 1959.** Use of dinitrosalicylic acid reagent for determination of reducing sugar. Analytical Chemistry, 31 (3): 426–428.
23. **Mizrach A., Nahir D., and Ronen B., 1992.** Mechanical thumb sensor for fruit and vegetable sorting. Trans. ASAE, 35 (1):247–250.
24. **O'Brien M., Fridley R.B., and Claypool L.L., 1978.** Food losses in harvest and handling systems for fruits and vegetables. Trans. ASAE, 21(2):386–390.
25. **Park S.W. and Hong S.J., 1997.** Distribution of sugars and organic acids within a fruit in three pear cultivars. 5th Int. Symp. on Fruit, Nut, and Vegetable ProductionEngineering, Davis, California, USA, S15(26):1–6.
26. **Paulus I. and Schrevens E., 1997.** A methodology to study the interaction of external features of apples on human quality classification. 5th Int. Symp. on Fruit, Nut, and Vegetable Production Engineering, Davis, California, USA, S2(1):1–6.
27. **Roudot A.C., Duprat F., and Wenian C., 1991.** Modeling the response of apples to loads. J. Agric. Eng. Res., 48, 249– 259.
28. **Rybczyński R., Dobrzański B. Jr., and Patyra T., 1997.** A sorting machine for commercial's fruit quality improvment. Food Processing and Packing Technology, China Machine Press, 77–83.
29. **Shewfelt R.L. and Prussia S.E., 1993.** Postharvest Handling - a Systems Approach. Academic Press, San Diego.
30. **Shmulevich I., Galili N., and Rosenfeld D., 1994.** Firmness testing device based on fruit acoustic response. AgEng Milano, Report N. 94–G–080: 1–9.
31. **Studman C. and Ouyang Li, 1997.** Bruise measurement by image analysis. 5th Int. Symp. on Fruit, Nut, and Vegetable Production Engineering, Davis, California, USA, S12(5):1–7.
32. **Studman C.J., 1994.** Quality in fresh fruit - Meaning, measurement and mainteance. AgEng'94 Milan, Report N. 94–G–067, 1–9.
33. **Studman C.J., 1994.** Design of apple grading tables. Project report, New Zealand Apple and Pear Marketing Board, Wellington, New Zealand.
34. **Tsukamoto M., 1981.** Studies on the mechanical injury of fruit: II. Susceptibility to impact and compression in apple fruit as related to storage periods and fruit portions. J. Jpn. Soc. Hort. Sci., 49, 571–575.
35. **Van Woensel G., Wouters A., and De Baerdemaker J., 1987.** Relation between mechanical properties of apple fruit and sensory quality. J. Food Proc. Eng., 9:173–189.
36. **Watada A., 1993.** The methodology for the determination of the quality of fruits and vegetables. Influence of new technologies. Paper 37, International symposium on the Quality of Fruit and Vegetables: Influence of Pre- and Post-harvest Factors and Technology. Int. Society for Horticultural Science, Chania, Greece.
37. **Whitlock D., Armstrong P., Brusewitz G., and Stone M., 1997.** The effect of apple shape characteristics on orientation during rolling. 5th Int. Symp. on Fruit, Nut, and Vegetable Production Engineering, Davis, California, USA, S14(2):1–6.
38. **Yantarasri T., Kawano S., and Sornsivichai J., 1997.** Nondestructive NIR technique for sweetness measurement of mango fruit. 5th Int. Symp. on Fruit, Nut, and Vegetable Production Eng., Davis, California, S15(22):1–6, USA.