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THE DETERMINATION OF HARVEST INDEX OF 'ŠAMPION' APPLES INTENDED FOR LONG STORAGE

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ABBREVIATIONS IN TEXT

OHD – optimum harvest date.
TSS – total soluble solids,
TA – titrable acidity,

Abstract. The harvest date is crucial for the storability of 'Šampion' apples intended for long storage. Only apples picked at the optimum maturity stage are suitable for storage over 3 months because of better storage potential and organoleptic quality. The research was conducted in the cold storage facility and laboratory of the Department of Pomology of the Poznan University of Life Sciences between 1999 and 2006 and was designed to evaluate and determine the Streif index for 'Šampion. Fruits were collected every 4–5 days starting some weeks before the estimated OHD. Maturity at harvest was evaluated in terms of firmness, TSS, starch disintegration, ground colour and titrable acidity. Fruits were stored in a cold storage facility for 3 months. The storability of apples was evaluated after the equal number of days of storage respectively to their harvest date. The evaluation was based on subjective quality judgments and measurements made after storage. After eight years of study the optimal value of the Streif index for 'Šampion' was determined at 0.12. The Streif index method was recognized as the basis for determining the harvest date of the apple cultivar 'Šampion'. Too early or too late harvest brought about substantial quality and quantity losses of 'Šampion' apples during storage.

Key words: storability, fruit quality, optimum harvest date, Streif index

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INTRODUCTION

'Šampion' has been one of the most important cultivar in Poland for many years [Bruille and Barritt 2004]. It owes its status due to high productivity, easy cultivation and popularity among consumers. However, as a late-autumn cultivar, it is not especially suitable for long storage. Besides such factors as the rootstock [Łysiak 1998, Łysiak and Kurlus 2000] or the age of a tree [Kapłan and Baryła 2005] also the correct determination of the harvest date is crucial for the storability, just like in the case of 'Elstar', which has similar storability as 'Šampion' [Zude-Sasse at al. 2000].

Only apples picked at the optimum maturity stage are suitable for storage over 6 months because of better storage potential and organoleptic quality [Streif 1996].

In Poland fruit growers determine the harvest date based on the fruit appearance, firmness or sometimes the starch content. However, methods which rely on separate parameters are not sufficient since they do not allow to predict correctly the harvest date each year [Streif 1996, Łysiak 1998].

Trials aimed at combining several parameters in one index have been conducted for a long time [de Jager and Roelofs 1996]. Some of the pioneering work was done by Blanpied [1974], who combined firmness and TSS to distinguish samples that would develop typical 'Delicious' flavour. The starch development was considered to give no satisfactory judgment, but the combination of the two above parameters also gave relatively much error. It was not until the publications of Streif [1983] and later of de Jager and Roelofs [1996] joined by publications in Poland: Skrzyński [1996], Rutkowski et al. [1996] and Łysiak [1998] that the usefulness and efficiency of the index method to determine the harvest maturity date was shown. The index (often referred to as the Streif index) combines the measurement of three parameters which change fast during the pre-harvest period to one value. The index fluctuations, if observed in the period starting a dozen days before harvest, allow to determine the optimum harvest date a few days in advance.

The value of the index, the efficiency of which can be assessed only after the storage period, may fluctuate from year to year [Skrzyński 1996, de Jager and Roelofs 1996]. Also its average value may differ depending on the climatic and soil conditions prevailing in the country where it is applied, which has been demonstrated by Streif [1996] and Luton [1996], who measured the Streif index values in Southern Germany and England within the same eight years.

This work presents the results of an eight-year research designed to determine the Streif index for 'Šampion', one of the most frequently grown cultivars in Poland. The index value determined based on the specific climatic and soil conditions prevailing in Wielkopolska Province may, however, require slight adjustments when applied in other regions.

MATERIALS AND METHODS

The research was conducted in the experimental orchard, cold storage facility and laboratory of Department of Pomology of the Poznan University of Life Sciences between 1999 and 2006. Fruits were picked from trees of 'Šampion' cultivar planted in

1992 on M.26 rootstock in 4 × 2 m single row, the trees having a wide spindle shape. The orchard was protected and maintained in line with the recommendations for commercial orchards.

Sampling. Fruits were collected every 4–5 days starting some weeks before the estimated OHD. The time of beginning of the fruit collection process varied depending on the blooming period and weather conditions prevailing during the vegetation season. The sample size was 20 fruits picked from a minimum 10 trees, from 140 to 160 cm high, outside part of the tree, from the same east-southern side. Fruits over or under size, infected by pests or diseases were rejected. The fruits should represent the stage of maturity (in size and colour) of those fruits that will be harvested during the main harvest. In most years on the last four sampling dates also the fruits intended for cold storage were collected. The harvest was conducted according to the rules for picking samples, but the size of a single sample intended for storage was considerably larger and amounted to 4 boxes per 10 kg each box.

Measurements. Evaluation of maturity and ripening at harvest were done according to well known standard methods:

– Firmness: penetrometer (probe – 8 mm depth, 11 mm in diameter), two opposite sides of the fruit, in kgf,

– Refractometer value in %,

– Starch disintegration 10 points scale where 1 is no conversion and 10 is totally converted,

– Ground colour measured with Minolta colorimeter CIE L*a*b*,

– Titrable acidity: titration with 1n NaOH to 8.1 pH, mval × 100 ml^{-1}.

Storage condition and evaluation of storability. Fruits were stored in a cold storage room at 1–2°C and around 90% of RH for 3 months. The schedule of all measurements is shown in table 1. The storability of apples was evaluated after the same number of days of storage respectively to their harvest date. The evaluation was based on the judgment and on measurements. The judgment was made using sensoric tests, incidence of diseases and disorders, fruit weight loss and internal quality criteria (firmness, TSS, TA).

Each criterion was scored separately for each date of harvest. The scores were given according to following rules:

1. Loss of fruit weight was measured in each stored box. Ten fruits were numbered and weighed with the accuracy of 0.1g before and after storage. Scores were given according to an analysis of variance between the harvest dates. If there were no significant differences, each sample received 1 point. If the analysis showed a significant difference, a sample could receive 1, 2 or 3 points.

2. Incidence of disorders and diseases was scored separately according to the same rules as fruit weight loss. If percentage of non-healthy fruits was higher, then 10% for each (disorders or diseases) group sample received 1 point independently of the analysis of variance.

3. Firmness was scored according to the following point scale:

0 – below 4.0 kgf,

0.5 – 4.01 – 4.5 kgf,

1.0 – 4.51 – 5.0 kgf,

2.0 – 5.01 – 5.50 kgf,

3.0 – over 5.5 kgf.

Table 1. Schedule of experiments
Tabela 1. Harmonogram badań

No of measurement Numer pomiaru	Years and dates – Rok i data							
	1999	2000	2001	2002	2003	2004	2005	2006
1	1 IX	23 VIII	5 IX	22 VIII	9 IX	8 IX	7 IX	27 VIII
2	6 IX	28 VIII	10 IX	26 VIII	13 IX	13 IX	12 IX	31 VIII
3	11 IX	2 IX	15 IX	31 VIII	17 IX	18 IX	16 IX	5 IX
4	16 IX	7 IX	20 IX	5 IX	21 IX	23 IX	21 IX	15 IX
5	21 IX	12 IX	25 IX	10 IX	25 IX	28 IX	26 IX	20 IX
6	27 IX	17 IX	1 X	14 IX	30 IX	3 X	30 IX	25 IX
7	1 X	22 IX	5 X	19 IX	3 X	8 X	5 X	30 IX
8			10 X	24 IX				1 X
Date of end of storage Data końca przechowywania	3 I 2000	5 I 2001	14 I 2002	6 I 2003	12 I 2004	14 I 2005	16 I 2006	15 I 2007
Length of storage in days Długość przechowywania w dniach	113	124	110	122	118	114	121	121

Underlined dates present dates of harvesting sample for storage – Daty podkreślone przedstawiają terminy zbioru owoców przeznaczonych do przechowywania.
Double underlined dates present OHD based on Streif Index – Daty podkreślone podwójnie przedstawiają daty optymalnego terminu zbioru na podstawie indeksu Streifa.

The point scale was developed independently based on the research by Konopacka at al. [2003] which examined the relation between texture attributes and consumers' perception and found that minimum hardiness preferences for three examined cultivars are between 4.0 and 5.0 kgf.

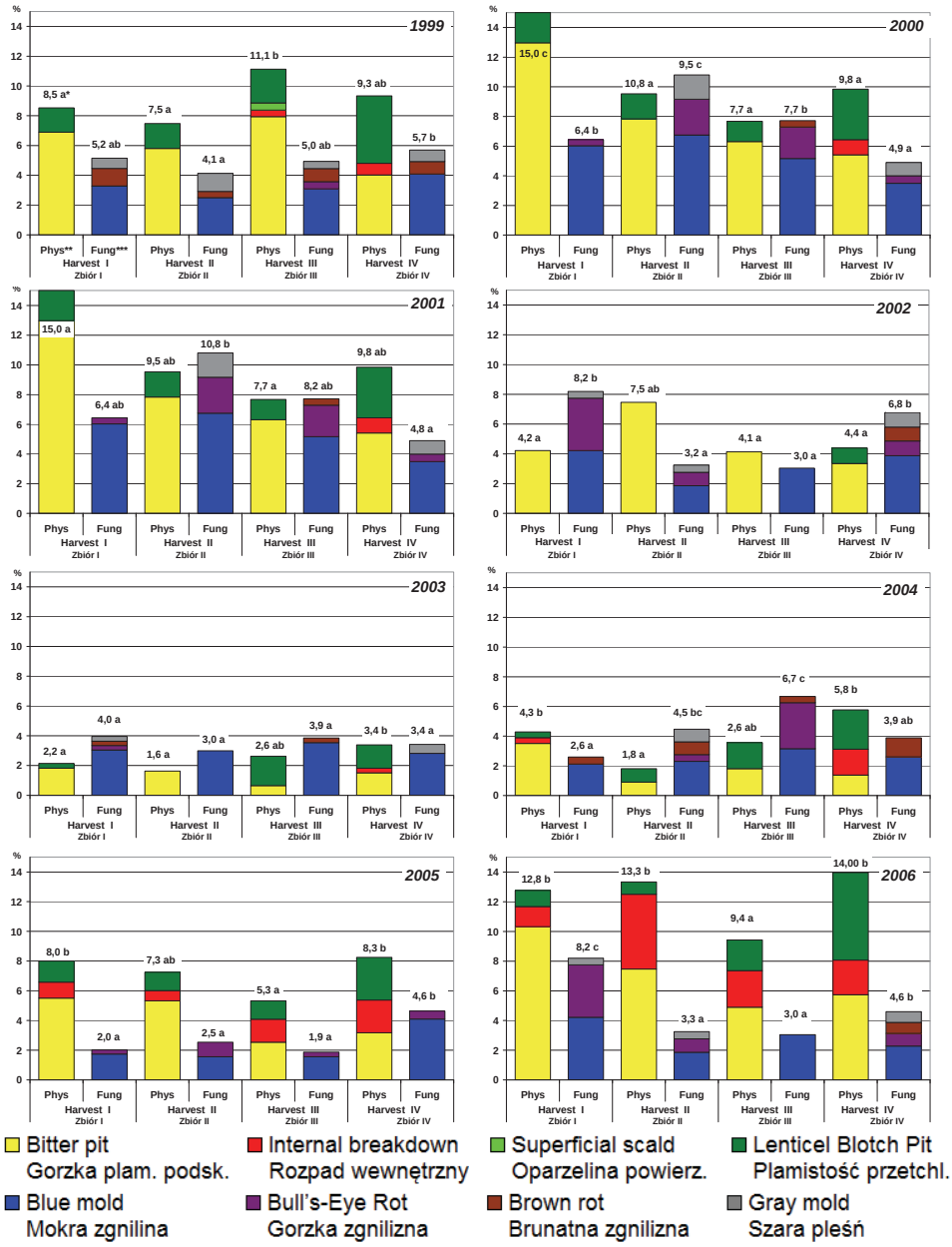
4. TSS and TA were scored separately according to the analysis of variance based on the same rules as the weight loss (scores 1–3). If TSS was below 11.5% and TA below 0.25, all samples received 1 independently of the analysis result.

5. Sensoric tests were made by 3–5 professional judges according to the overall acceptance on the market along the following scale: 0 – no acceptance on market, 1 – poor acceptance, 2 – good, 3 – excellent. The average judgment was rounded to 0.5 point.

All the measured data were subjected to the analysis of variance. The mean comparisons were performed using the Duncan test to examine differences ($P < 0.05$) among the harvest dates.

RESULTS AND DISCUSSION

As it could be expected [Streif 1983, de Jager and Roelofs 1996, Skrzyński 1996, Rutkowski at al. 1996, Łysiak 1998] too early or too late harvest affected negatively the storability of fruits due to higher incidence of physiological disorders and in some years



* Values designated with the same letters do not significantly differ in maturity stages, according to Duncan's test ($P > 0.05$) – Wartości oznaczone tymi samymi literami nie różnią się istotnie pomiędzy terminami zbioru wg testu Duncana dla ($P > 0,05$); ** Incidence of physiological disorders – Występowanie chorób fizjologicznych; *** Infection by fungal diseases – Porażenie chorobami grzybowymi

Fig. 1. Fruit losses after storage caused by physiological disorders and fungal diseases
Ryc. 1. Straty owoców po przechowywaniu spowodowane chorobami fizjologicznymi i grzybowymi

the occurrence of infections with pathogens causing fungus diseases (fig. 1). Despite a high variability of infections with pathogens causing fungus diseases, their occurrence was not found to be dependent on the degree of maturity related with the harvest date, unlike the observations made in some other studies [de Jager and Roelofs 1996]. In some years the incidence of diseases in the cold storage increased slightly for fruits collected at subsequent harvest dates (2004 and 2005), but a contrary situation was reported as well (2006). The bull's-eye rot disease caused primarily by the fungus *Pezicula malicorticis* (Jacks.), occurring on prematurely ageing fruits [Conway 1984], was not observed to be most intense in fruits collected at the last harvest date, i.e. the more mature fruits, in any of the eight years of the study. Probably the weather conditions and the protective measures undertaken in the orchard affected the incidence of fungus diseases more than did fruit ripeness.

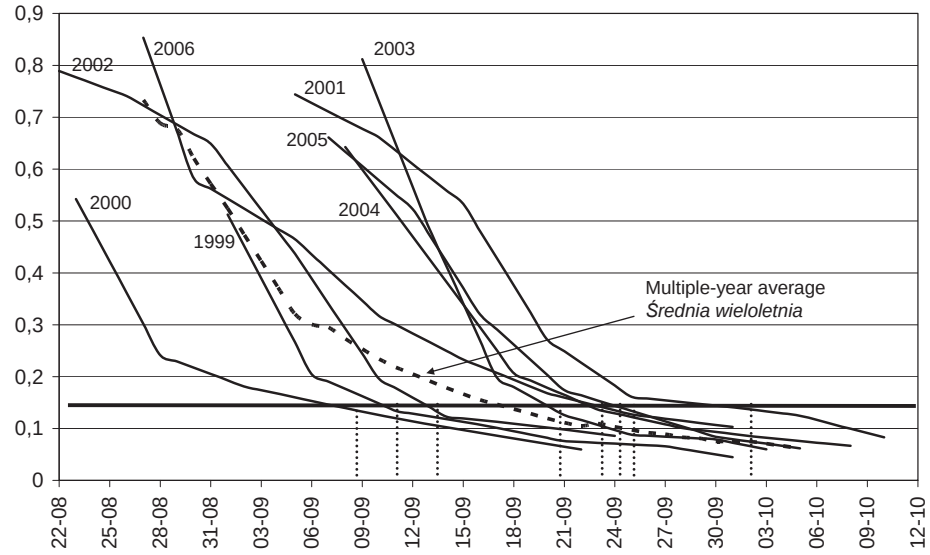


Fig. 2. Streif index curves in 1999–2006
Ryc. 2. Krzywe indeksu Streifa w 1999–2006

The incidence of bitter pit and other physiological disorders is closely related to the respiratory activity at harvest [Ferguson at al. 1999]. Other quality features including firmness and TSS also change fast during the ripening period and the fruits if harvested too late are too soft and show low TSS and acidity after storage. The firmness value for 'Šampion' below which some consumers will consider the fruits as unattractive amounts to 4.5 kgf. In two years covered by the study (2003 and 2004) the firmness value fell under this threshold after storage, which shows that the storage period of 3 months was too long. The fast decline of firmness and its small variation after storage might be due to the weather conditions in the growth period, as the year 2003 was char-

Table 2. Assessment according to a point scale of the quality aspects of fruit samples harvested on the respected dates examined after storage in the years 1999–2006 as compared to the Streif index

Tabela 2. Ocena punktowa parametrów jakościowych owoców po przechowywaniu pochodzących z poszczególnych zbiorów w latach 1999–2006 w porównaniu do wartości indeksu Streifa

Year Rok	Harvest No. Numer zbioru	Firmness Jędrność	TSS Zawartość ekstraktu	TA Kwasowość	Mass loss Ubytek masy	Physiological disorders Choroby fizjologiczne	Fungal diseases Choroby grzybowe	Senscoric test Test sensoryczny	Total Razem	Stref index Indeks Streifa
1999	I	2	2	2	3	3	2	2	16.0	0.134
	II	**3**	**1**	**2**	**3**	**3**	**3**	**2**	**17.0**	**0.107**
	III	2	2	1	1	1	2	1.5	10.5	0.076
	IV	1	1	1	1	2	1	1	8.0	0.066
2000	I	2	1.5	1	1	1	2	2	10.5	0.181
	II	2	1	1	2.5	2	1	1.5	11.0	0.146
	III	**1**	**2**	**1**	**3**	**2**	**2**	**1.5**	**12.5**	**0.113**
	IV	1	1	1	2	2	3	1	11.0	0.086
2001	I	1	2	2	1	1	1.5	1	9.0	0.161
	II	1	1	1.5	1	2	2	1.5	10.0	0.141
	III	1	1	1.5	2	3	1.5	1.5	11.5	0.125
	IV	**1**	**1**	**1**	**3**	**3**	**3**	**1**	**13.0**	**0.103**
2002	I	1	1	2	1	2	1	1	9.0	0.437
	II	1	1	1.5	2	1	3	1.5	11.0	0.196
	III	**1**	**2**	**1.5**	**2**	**3**	**3**	**1.5**	**14.0**	**0.123**
	IV	1	2	1	2	3	1	1	12.0	0.106
2003	I	0.5	1	2	1	2	3	1	10.5	0.198
	II	**1**	**3**	**2**	**1**	**3**	**3**	**1**	**14.0**	**0.126**
	III	0.5	2	2	1	1	3	1	10.5	0.088
	IV	0.5	3	1	1	1	3	1	9.5	0.079
2004	I	**1**	**2**	**2**	**2**	**2**	**3**	**2**	**14.0**	**0.136**
	II	1	1	1	3	3	1.5	2	12.5	0.101
	III	0.5	3	1	1	2.5	1	1	10.0	0.082
	IV	0.5	2	1	1	2	2.5	1	10.0	0.066
2005	I	1.5	2.5	2	1	1	1	1.5	12.5	0.320
	II	1.5	2	1.5	2	1	3	2	13.0	0.174
	III	**1**	**2**	**1.5**	**3**	**2**	**3**	**2**	**14.5**	**0.124**
	IV	1	1	1	1	1	2	1	8.0	0.084
2006	I	2	2	3	1	2	1	1	12.0	0.233
	II	1.5	1.5	2	2	1	3	1.5	12.5	0.168
	III	**1.5**	**1.5**	**2**	**2**	**3**	**3**	**2**	**15.0**	**0.127**
	IV	1.5	1	1	1	1	2	1.5	9.0	0.103

* bold characters indicate OHD estimated by Streif Index – czcionką pogrubioną oznaczono datę optymalnego terminu zbioru na podstawie indeksu Streifa

acterised by record temperatures in the summer months and the year following it also belonged to the warmest years of the eight years covered by the research. On the other hand, in 2001 and 2002 no differences were identified between the fruits harvested at different dates. Such variability of results suggests that the assessment of storage efficiency should be based on at least several parameters since only in this way it can be reliably determined which of the applied dates was most appropriate.

The fruit weight losses caused by transpiration and respiration and the low taste quality in most years were observed for the fruits picked too early (tab. 2). The measurement of all those parameters after an equal storage period showed that the OHD for the respective eight years differed by even 28 calendar days since it ranged from 12 September (in 2000) to 10 October (in 2001) (tab. 1).

The value of the Streif index oscillated between 0.103 in 2001 and 0.136 in 2004 (tab. 2). The index standard deviation amounted to only 0.0113 within eight years, which proves a relatively small variability during the trial years. The average index value amounted to 0.11993 ≈0.12. It should however be remembered that the measurements were carried out in five-day intervals and the measurement frequency affects the final result [Streif 1996]. The extension of the experiment to more than eight years would have probably reduced the spread of the results. Still, the result obtained for the eight years very different in terms of vegetation onset and weather conditions allowed for obtaining a very coherent results which can provide a basis for determining the OHD for 'Šampion'. The curves of the Streif index for the individual years show that the pace and nature of changes are very similar whereas the differences concern mainly the dates on which those changes started (fig. 2). However, to avoid a short-term fluctuation in values referred to by Jager and Roelofs [1996] at least 5 measurements should be carried out to determine the course of the curve.

The above findings allow to recommend this method for practical application all the more as it requires only the basic tools such as the penetrometer, refractometer and Lugol's iodine, which each fruit grower can afford with no need for substantial outlays.

CONCLUSIONS

1. Too early or too late harvest brought about substantial quality and quantity losses of the apple cultivar 'Šampion' during storage.

2. The Streif index method can be the basis for determining the harvest date of the apple cultivar 'Šampion'.

3. The value of the Streif index for 'Šampion' is 0.12.

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WYZNACZANIE INDEKSU ZBIORU JABŁEK ODMIANY 'ŠAMPION' PRZEZNACZONYCH DO DŁUGIEGO PRZECHOWYWANIA

Streszczenie. Optymalna data zbioru decyduje o zdolności przechowalniczej owoców odmiany 'Šampion' przeznaczonych do długiego przechowywania. Tylko owoce zebrane w optymalnej fazie rozwoju mają wystarczającą zdolność przechowalniczą i właściwości jakościowe pozwalające na przechowywanie ich przez okres ponad 3 miesięcy. Badania przeprowadzono w chłodni i laboratorium Katedry Sadownictwa Uniwersytetu Przyrodniczego w Poznaniu w latach 1999–2006 i polegały na ocenie przydatności i wyznaczeniu wartości indeksu Streifa dla jabłek odmiany 'Šampion'. Próby owoców zbierano co 4–5 dni, rozpoczynając na kilka tygodni przed przewidywanym terminem zbioru. Fazę dojrzałości i jej tempo oceniano, mierząc jędrność, zawartość ekstraktu, stopień rozkładu skrobi, barwę podstawową skórki oraz kwasowość. Owoce przechowywano w chłodni

przez 3 miesiące. Jakość owoców z poszczególnych zbiorów oceniano po tej samej liczbie dni przechowywania. Ocenę oparto na pomiarach jakościowych oraz ocenie sensorycznej przeprowadzonej przez panel ekspertów. Ośmioletnie badania pozwoliły ustalić wartość indeksu na 0,12. Metoda indeksowa ze względu na swą powtarzalność i precyzję została uznana za dobrą dla wyznaczania terminu dojrzałości zbiorczej odmiany ‘Šampion’. Zbyt wczesny oraz zbyt późny zbiór powodowały istotny spadek jakości oraz zmniejszały zdolność przechowalniczą jabłek ‘Šampion’.

Słowa kluczowe: zdolność przechowalnicza, jakość owoców, optymalny termin zboru, indeks Streifa

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