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BIOLOGY OF FRUCTIFICATION – QUALITATIVE CHANGES OF ACHENES IN COMMON SUNFLOWER (*HELIANTHUS ANNUUS* L.) DURING THEIR RIPENING

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ABSTRACT. The experiments were conducted in a 4-year cycle at the Przybroda experimental station of the Poznań University of Life Sciences. One open pollinated variety – Wielkopolski and two hybrid varieties, 'Frankasol' and 'Coril' were tested. To determine qualitative changes of achenes – the percentage of fat, protein, water, fibre, ash and nitrogen-free extract. The hybrid cultivars did not always exceed the open pollinated cultivar in terms of fat and protein contents in achenes. In the process of achene ripening no definite correlation was observed between the increase in fat contents in fruits and a decreasing protein proportion. Only a low level of precipitation in the period of fruit ripening in 1999 caused an increase in the percentage content of fat in achenes at the simultaneous reduction of protein content. In the course of fruit ripening the share of fat increased markedly, water content decreased, and to a lesser degree the contents of fibre and nitrogen-free extract also decreased, while the shares of protein and ash remained at a similar level.

KEY WORDS: sunflower, achenes, qualitative changes, ripening

INTRODUCTION

Common sunflower (*Helianthus annuus* L.) originates from the south-western part of the USA and northern Mexico (Podsolnečnik 1975). As it was shown by ethnographic and archeological studies, already centuries before the arrival of European to those areas native Americans inhabiting those regions obtained sunflower oil, which they added to food and used as hair lotion (Olejniny 1992). Fat collected from pressing of whole achenes is dark in colour, since pigments from the fruit coat are dissolved in it. High quality oil is produced only from hulled fruits (Mieszkalski et al. 1996).

Sunflower oil, constituting a valuable raw material used in many branches of industry, has been extensively tested in terms of its chemical composition (Schuster et al. 1972, Zimmerman and Fick 1973, Greco and Alba 1983) and its content in achenes (e.g. Muśnicki 1975, Karlovic et al. 1988, Łuczkiewicz 1992, Tonev 1996). However, the studies have concerned only fruits in the processing maturity stage. There is a very limited number of studies discussing quantitative and qualitative changes in achenes in the course of their ripening. In relation with the above the aim was to follow changes in the chemical composition of fruits occurring in the course of their ripening.

MATERIAL AND METHODS

The experiments were conducted in a 4-year cycle at the Przybroda Experimental Station of the Poznań University of Life Sciences. Objects of the study included a Polish open pollinated variety ('Wielkopolski') and two hybrid varieties, i.e. one French ('Frankasol') and one American ('Coril'). Experimental conditions were presented in detail in a previous study by Kluza-Wieloch (2011).

Fruits for chemical analyses were collected from the outer portions of the heads at 7-day intervals from 10 specimens from two replications for each variety. The first sample was collected a week after blooming of this inflorescence section and the last at full maturity, from the outer part of the capitulum. In the 4-year cycle of the experiment achenes were analysed using the near infrared reflectance spectroscopy (NIRS) to determine the percentage of fat, protein, fibre, ash and nitrogen-free extract after a previous calibration of the device with the use of standard methods (Podkówka et al. 1996, Czarnik-Matusewicz and Korniewicz 1993). In the last two years of the study the percentage water content in fruits was also analysed. Additionally water loss in fruits and in hulls was determined in 100 achenes of each cultivar in six replications. Plant material was placed in a laboratory drier at 60°C and the next day it was weighed on a laboratory balance. Results of the analyses are presented in Figures 1-12.

RESULTS

Fat content in the analysed cultivars increased markedly between week 1 and week 3 after flowering (from 5 to 40%). Between the 3rd and 5th sampling dates this increase was less intensive. One week before processing maturity the proportion of oil in achenes stabilised. At all times the highest fat content was recorded for the hybrid cv. 'Coril' (49%), while it was lowest in cv. 'Frankasol' at 43% (Fig. 1). Fruits richest in oil were found in the analysed cultivars in 1999 (50%). The dynamics of changes in fat content were similar in all the four years of the study (Fig. 2).

Changes in the percentage share of protein in fruits were less pronounced that those in fat content. At all times the lowest protein proportion was recorded in the hybrid 'Frankasol' (17.5%), while it was highest in cv. 'Coril' (19.1%). In this cultivar the share of protein underwent minimal fluctuations between the first and the last achene collection dates (Fig. 3). The greatest changes in the contents of this nutrient were observed in the year 2000, while the smallest changes were recorded in 1998. The year 2000 was characterised by the greatest accumulation of protein in fruits (22%), while its lowest amount was observed one year earlier (14.7%). In individual years of the study there were situations when one year achenes contained more protein at the beginning than immediately before harvest, whereas in the next years the trend was opposite (Fig. 4).

Fibre content dropped almost linearly up to week 5 after flowering from 31.5% to 13.6%. It was always the lowest in the hybrid 'Coril' (12.5%), while it was highest in 'Frankasol', amounting to 17.5% (Fig. 5). In the years 1999-2000 the smallest changes were observed in the proportion of fibre in achenes (from 25 to 15%). The biggest decrease in its content was observed between the 1st and the 3rd dates of fruit sampling (from 34 to 19%). The greatest variation in the share of fibre was recorded in 1998 and in 2001 – from 34 to 14.8% (Fig. 6).

The share of ash showed minimal differences between cultivars during ripening – from 4.6 to 3.4% (Fig. 7). Irrespective of sampling date the highest ash content was recorded in 2000 (5.2%), while it was lowest in 1998 (3.2%). In each season ash content stabilised at week 4 of harvest (Fig. 8).

The content of nitrogen-free extract in achene dry matter of each cultivar decreased with the progress of ripening from 50 to 16%. This trait was stabilised

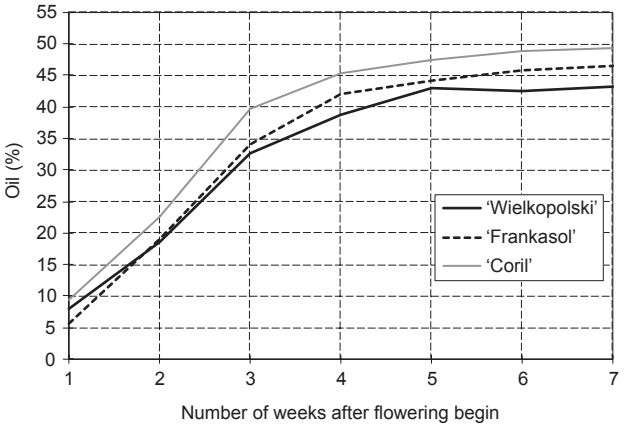

Fig. 1. Changes of oil content during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001)

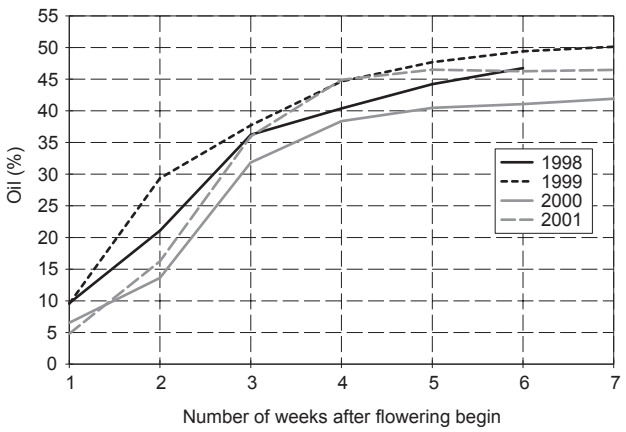

Fig. 2. Changes of oil content during formation and ripening of fruits of three sunflower cultivars (averages of three cultivars)

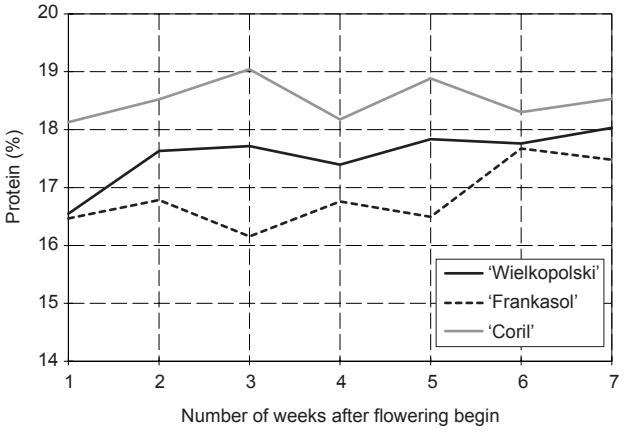

Fig. 3. Changes of protein content during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001)

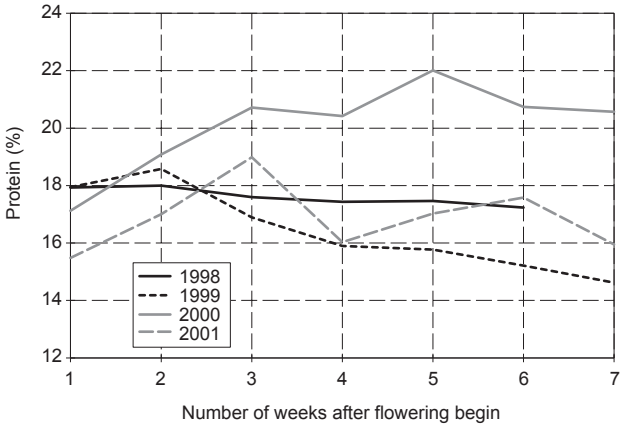

Fig. 4. Changes of protein content during formation and ripening of fruits of three sunflower cultivars (averages of three cultivars)

as early as week 4 from flowering (Fig. 9). The smallest changes in the share of these compounds were observed on the first year of the experiment (from 34 to 20%), while the greatest variation was found in the last vegetation season – 60 to 18% (Fig. 10).

Water content in whole achenes decreased almost linearly with progress in their ripening from 86 to 20%. Dynamics of water loss from fruits were similar in all cultivars. At processing maturity, found at week 6 from flowering, water content in achenes was on average 30%. At that time point hybrids contained approx. 7%

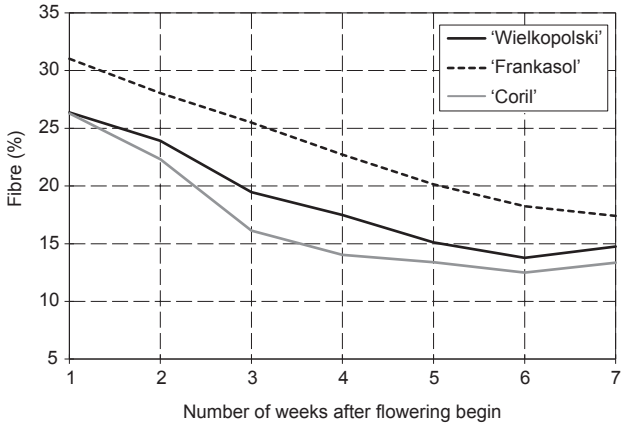

Fig. 5. Changes of fibre content during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001)

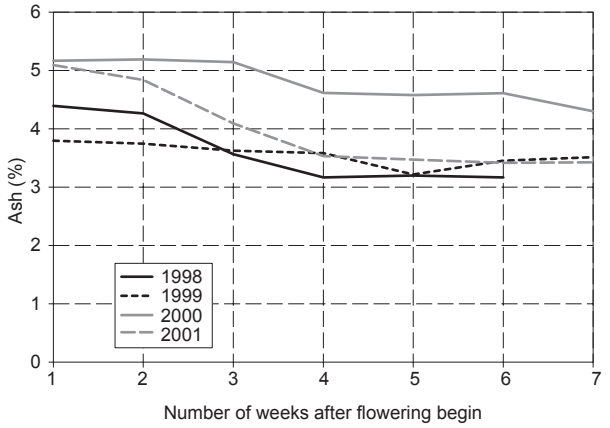

Fig. 8. Changes of ash content during formation and ripening of fruits of three sunflower cultivars (averages of three cultivars)

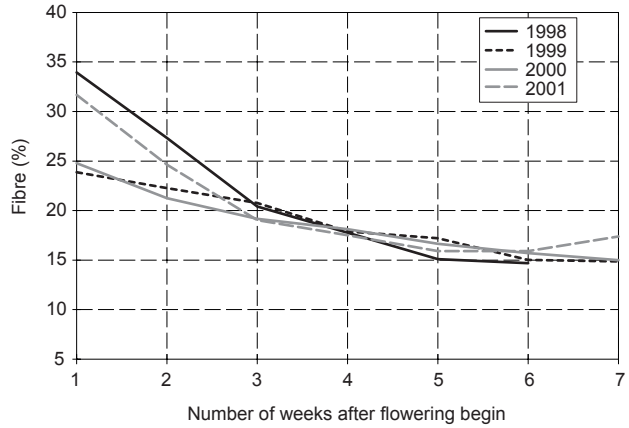

Fig. 6. Changes of fibre content during formation and ripening of fruits of three sunflower cultivars (averages of three cultivars)

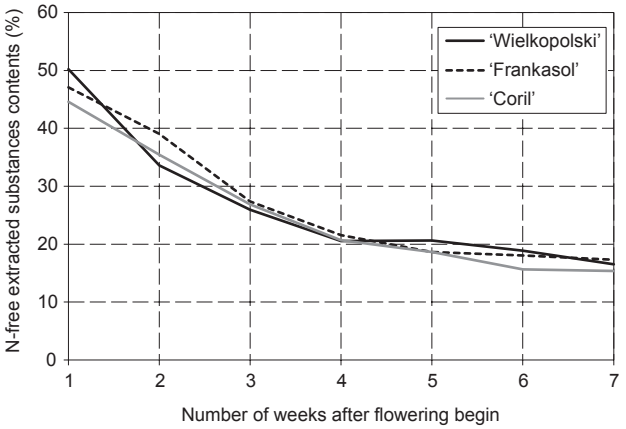

Fig. 9. Changes of N-free extracted substances contents content during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001)

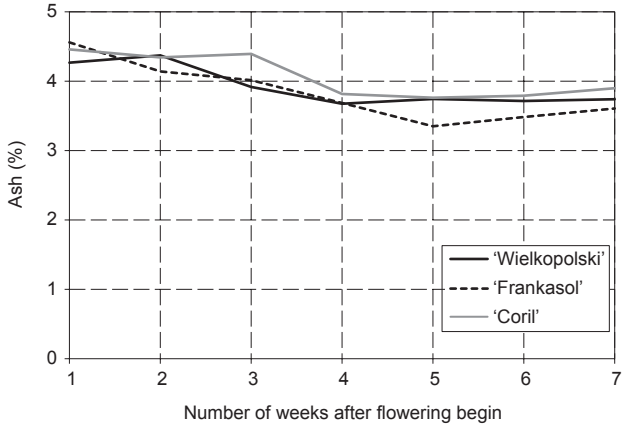

Fig. 7. Changes of ash content during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001)

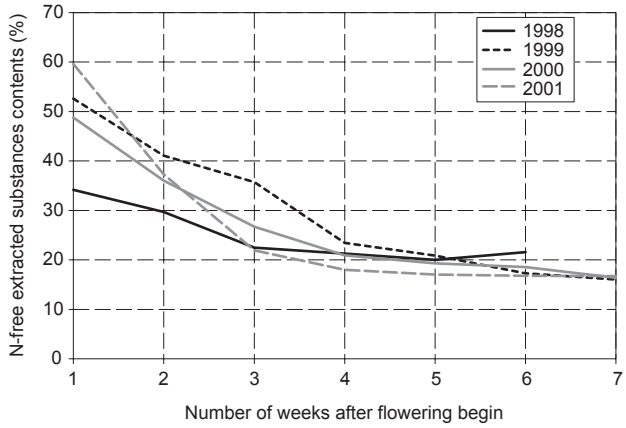

Fig. 10. Changes of N-free extracted substances content during formation and ripening of fruits of three sunflower cultivars (averages of three cultivars)

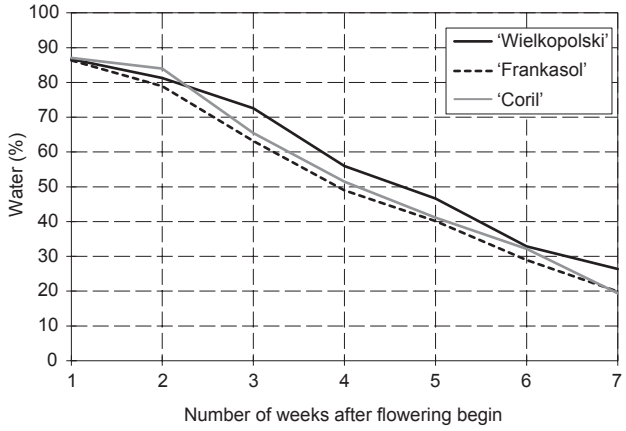

Fig. 11. Changes of water content during formation and ripening of fruits of three sunflower cultivars (averages of 2000-2001)

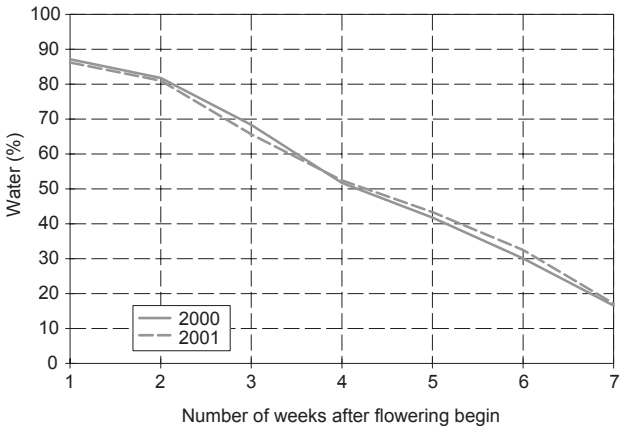

Fig. 12. Changes of water content during formation and ripening of fruits of three sunflower cultivars (averages of three cultivars)

less water than the open pollinated cultivar (Fig. 11). Achenes in the years of analyses contained from 86 to 18% water. At the last four fruit sampling dates in 2001 its content was slightly lower (Fig. 12). This was caused by weather conditions. In the pericarps water content in individual weeks of analyses decreased markedly in all cultivars. However, in the last week of achene collection hulls contained more water than seeds.

DISCUSSION

Dorrell (1978) investigated the effect of harvest on the concentration of oil and fatty acids in forming fruits before they reached full maturity. He collected them from two open pollinated cultivars at 7-day intervals, in the first year starting from day 21 after flowering up to day 49, while in the second year it was from day 7 to 27, and at day 49. The share of oil in achenes changed slightly in the course of the first days, while it increased markedly at around day 21, which was not confirmed in the presented analyses. Fat content in the first season was highest between days 28 and 35, while in the next season it as late as the end of the analyses. Kaffka et al. (1982) determined oil content in sunflower seeds using the NIRS technique. Achenes of different cultivars harvested at different ripening stages contained 1.4-54.6% fat, while in the presented study they contained 5-50% oil to reach the level of 43-49% in the processing maturity stage (Figs 1-2). Vasiliev (1990) showed that with the progress of fruit ripening the amount of oil stabilised around day 30-35 after the end of blooming, which was also observed in the presented study. Federowska (1971) stated that the proportion of oil in maturing fruits, from the semi-processing maturity phase to full maturity, increased by as little as 6%. In contrast, over the same time period the qualitative composition of fat changed markedly, as the share of linolic acid increased considerably. Triki et al. (1997) studied lipoglycerol metabolism at different stages of sunflower fruit ripening. Three weeks after the end of blooming the optimal stage of lipogenesis was found in achenes.

In a study by Kaffka et al. (1982) achenes of different cultivars harvested at different maturity stages contained 12.4-35.3% protein and 3.8-30.0% fibre. Protein content in the described experiment in the course of fruit ripening fell within the range of 15-22%, while fibre content was 13.6-34%, respectively (Figs 3-6).

The amount of water, according to the study by Federowska (1971), decreased with the progress of achene ripening. In the period of semi-processing maturity, when flower heads gained light yellow colouring, fruits contained 40-56% water. At harvest this value was only 15-23%. This was confirmed both by this experiment and other studies (e.g. Gupta and Das 1997, Mieszkalski et al. 1996, Vasiliev 1990). Dorrell (1978) observed that water content decreased towards the end of observations, with the process being strongest between days 29 and 49. In a study by Kaffka et al. (1982) at different harvest dates it amounted to 3.1-28.9%. Water content at physiological maturity reached 35-45%, with high levels recorded in early sunflower cultivars (Mundstock and Mundstock 1988 b).

Mundstock and Mundstock (1988 a) observed that the stabilisation of the qualitative composition of fruits lasted for 21-40 days, occurring with the greatest frequency between days 23 and 29 after the end of blooming. The same authors in another study (Mundstock and Mundstock 1988 b) stated that the compounds were accumulated in the forming achenes from days 21 to 37, depending on the year of the study and type of cultivar.

CONCLUSIONS

1. In the process of achene ripening no definite correlation was observed between the increase in fat contents in fruits and a decreasing protein proportion. Only a low level of precipitation in the period of fruit ripening in 1999 caused an increase in the percentage content of fat in achenes at the simultaneous reduction of protein content.

2. In the course of fruit ripening the share of fat increased markedly, water content decreased, and to a lesser degree the contents of fibre and nitrogen-free

extract also decreased, while the shares of protein and ash remained at a similar level.

3. The hybrid cultivars did not always exceed the open pollinated cultivar in terms of fat and protein contents in achenes.

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