



## COMPARISON OF THE CARBOHYDRATE CONTENT IN APPLES AND CARROTS GROWN IN ORGANIC AND INTEGRATED FARMING SYSTEMS

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### ABSTRACT

The aim of this study was to compare some quality parameters of apples and carrots from organic and integrated farming systems. In addition, the cultivars of carrots were grown in two plant densities (600 or 900 thousand plants per hectare). The fructose, glucose, saccharose and dry matter content of seven apple cultivars (Florina, Zvonková, Topaz, Šampion, Ontario, Melrose and Idared) and two carrot cultivars (Aftalon F1 and Cortina F1) were analysed by HPLC and gravimetric methods, respectively. Significant differences were found between organic and integrated apple samples. The interactions between cultivars and farming methods were also significant ( $p < 0.0001$ ). The dry matter and sugar level tendencies were not the same for all apple cultivars. Conversely, more consistent data were obtained for the two carrot cultivars. The bio carrots of both cultivars showed significantly lower dry matter content ( $p = 0.0004$ ) and higher carbohydrate content ( $p_{\text{fructose}} = 0.0303$ ,  $p_{\text{glucose}} = 0.0003$ ,  $p_{\text{sucrose}} = 0.0083$ ) than the samples from integrated production. Other factors like cultivar and plant density also played an important role in sugar content in carrots. Different densities of plants significantly affected the glucose content ( $p = 0.0373$ ). Cultivar Aftalon F1 showed higher concentration of monosaccharides compared to Cortina F1 ( $p_{\text{fructose}} = 0.0001$  and  $p_{\text{glucose}} < 0.0001$ ).

**Keywords:** fructose; glucose; sucrose; dry matter; organic farming

### INTRODUCTION

There has been an increasing interest in organic farming in recent years. One of the main positives of organic production is its friendly approach to the environment. There are several studies dealing with the assessment of the quality of products from organic and integrated agricultural farming systems in order to objectively evaluate possible differences in the quality parameters (Hogstat et al., 1997; Bavec et al., 2010; Bertazza et al., 2010). Organic farming aims to eliminate the application of agricultural chemicals and use natural materials both in plant protection products, as well as in animal nutrition. Organic products may contain lower levels of pesticide residues in comparison with conventional or integrated production (Róth et al., 2007). It should be noted however, that studies published so far have not clearly proved higher nutritional quality of organic or conventional production.

Apples and carrots are among the most commonly grown fruits and vegetables in our climate. They represent very tasty food from the sensory point of view due to the presence of carbohydrates and organic acids. Carbohydrates are the main source of energy in human nutrition necessary for normal muscle and brain functions. They also protect cells against some external harmful effects (Clarková, 2000). Fructose, glucose and sucrose (saccharose) belong to the main available carbohydrates in apples and carrots.

According to Kopec (1998) the total carbohydrate content in apples is  $144 \text{ g.kg}^{-1}$  and the value for carrots is  $97 \text{ g.kg}^{-1}$ . The composition of carbohydrates in fresh apples was also analyzed by Suni et al. (2000). Total carbohydrate content ranged from 615 to  $716 \text{ g.kg}^{-1}$  of dry matter; fructose was the dominant component (57%). Soria et al. (2009) analysed the carbohydrate content in carrots by gas chromatography. The concentrations of fructose were 20 -  $244 \text{ mg.g}^{-1}$ , glucose 17 -  $245 \text{ mg.g}^{-1}$  and sucrose 137 -  $689 \text{ mg.g}^{-1}$  of dry matter.

Cultivar, climate conditions, soil type, method of cultivation and storage conditions are very important parameters for the internal quality of apples and carrots. Weibel et al. (2000) tested "Golden Delicious" apples. They grew simultaneously organic and integrated apples in a similar microclimate. They compared the following quality parameters: fruit hardness, content of carbohydrates, malic acid, minerals, phenols and vitamins C and E. Sensory analysis was also carried out. All samples from organic production had significantly harder fruit flesh and also had a better taste than conventional fruits. Bio apples contain more phosphorus and phenolics. Róth et al. (2007) analyzed "Jonagold" apples from organic and integrated production from three different regions in Belgium with similar climatic and soil characteristics. The analysis did not prove that there is convincing evidence of a difference in nutrient content between organic and conventional samples. Bordeleau (2002) compared organic and conventional varieties of

“Golden Delicious” apples. Significant differences were found in the acidity, size and colour of the fruit. In contrast, no difference was detected in carbohydrates, pH, dry matter content or the hardness of the apples. The author, however, stated that there are differences between organic and conventional food for only some parameters, but the final quality is affected by many other factors. In addition, the organoleptic survey of **Nagy et al. (2012)** did not identify any differences between organic and integrated products.

**Rembalkowska (2003)** analyzed the effects of organic methods on the quality of vegetables during production, storage, and on the way to the consumer. The nutritional and sensory qualities of carrots and potatoes from organic and conventional farming were compared. It was found that the organic vegetables had lower yields, but some of its nutritional and sensory quality attributes were better than those conventional products. But according to **Seljasen et al. (2013)** sensory and chemical quality parameters of carrots are determined mainly by genetic and climate-related factors and only to a minor extent by cultivation method.

Although experiments with animals fed with organic feed, showed that animal health and reproductive performance had been slightly improved, similar findings have not been identified in humans yet (**Magkos et al., 2003**).

The aim of this paper was to study selected quality parameters (concentration of carbohydrates and dry matter content) of the organic and integrated production of seven apple and two carrot varieties and to establish the similarities and differences between these farming systems. The main hypothesis was whether products from organic farming have a higher nutritional value than products from integrated systems.

## MATERIAL AND METHODOLOGY

### Material

Seven apple cultivars, “Florina”, “Zvonkové”, “Topaz”, “Šampion”, “Ontario”, “Melrose” and “Idared”, were selected for the experiment. All these cultivars were grown in organic and integrated farming systems. The apples from organic farming were from certified orchards near the town of Chrudim. Apples of the same cultivars from an integrated system were harvested at the same year (2012) in a demonstration orchard at the Czech University of Life Sciences in Prague. Two cultivars of carrots (“Afalon F1” and “Cortina F1”) were grown at the same place. The density of carrots was 600 or 900 thousand plants per hectare. Integrated samples were fertilized using 80 kg of nitrogen (80% in the form of urea before sowing and 20% in the form of ammonium nitrate with calcite during vegetation) per hectare; organic carrots were treated by 1.5 t.ha<sup>-1</sup> of Organica fertilizer (Agro CS, Czech Republic).

### Dry matter content determination

The dry matter content of samples (1 g) was analysed by using infrared balances (Precisa 310M, Precisa HA300, Precisa Instruments AG, Switzerland). Drying under infrared light was performed at 105 °C for about 20 minutes to a constant weight with a difference of less than 1 mg min<sup>-1</sup>. Each sample was measured three times.

### Instrumental analysis of sugars

A high-performance liquid chromatographic (HPLC) method was used to determine the fructose, glucose, and sucrose content of apples and carrots. The HPLC system (Varian Star 9010) consisted of ion exchange resin-based column (Aminex HPX-87H) heated to 55 °C, a solvent system of 0.005M H<sub>2</sub>SO<sub>4</sub>, a flow rate of 0.6 mL.min<sup>-1</sup>, and a refractive index detector (Varian RI-4) heated to 35 °C. The calibration curve was determined using standard solutions of sucrose, glucose and fructose at concentrations of 0.5, 1.0, 2.0 and 3.0 g.100 g<sup>-1</sup>. Their retention times were 8.09, 9.62 and 10.45 minutes respectively. The correlation coefficients of the calibration curves ( $R^2$ ) were 0.9932 for sucrose, 0.9973 for glucose and 0.9960 for fructose.

### Samples preparation

All fruits were cleaned before analysis. Parts that are not consumed were removed. The edible parts were homogenised by a Fagor B-515M blender (Electrodomésticos, Spain). Thirty grams of the homogenised sample plus 60 g of demineralised water were thoroughly mixed and taken for the analysis. The sample was filtered through the filter paper and then through the Simplepure NY 0.45 µm filter. The filtrate was injected into HPLC loop (20 µL). The analysis of one sample took 15 min.

### Statistical analysis

Linear regression equations, regression coefficients ( $R^2$ ) as well as other results were calculated from the data using Microsoft Office Excel 2007. The impact of factors of “cultivar”, “farming system” and “density” was evaluated using multi-way (two-way for apples and three-way for carrots) analysis of variance (ANOVA). Tukey's test was used to calculate statistically significant differences between samples using statistical software Statistica 12 (StatSoft Inc.). For all statistical tests, a 5% level of significance was used.

## RESULTS

Dry matter content of apples and carrots grown under organic and integrated systems are given in Tables 1 and 2. The results are expressed as arithmetic mean ± standard deviation. They were in the range of 9.63% - 17.41% for apples and 10.74% - 14.39% for carrots. The sucrose, glucose and fructose content of apples and carrots grown under organic and integrated systems are given in Tables 3 and 4. The results are expressed as arithmetic mean ± standard deviation. It is seen from Table 3 that fructose content was the highest in all varieties of apples followed by glucose and sucrose, which is in line with **Soria et al. (2009)** and **Nagy et al. (2012)**.

Cultivar “Šampion” from organic farming had the highest total carbohydrate content (160 g.kg<sup>-1</sup>) (Figure 1). The lowest value was recorded in the cultivar “Topaz” from organic farming (65 g.kg<sup>-1</sup>). Cultivar “Aftalon F1” (density 600) from organic production showed the highest value of carbohydrates among carrots (Figure 2, Table 4).

Contrary to other analysed samples this variety had the highest content of glucose, which was even higher than the fructose content. Cultivar “Cortina F1” (density 600) from integrated production had the lowest carbohydrates value.

**Table 1** Dry matter content (%) of apples grown under organic and integrated systems.

Cultivar	Farming system	
	interated	organic
IDARED	9.6 ±0.3	13.5 ±0.1
MELROSE	12.6 ±0.1	16.0 ±0.2
ONTARIO	17.4 ±0.1	13.5 ±0.1
ŠAMPION	13.4 ±0.1	15.7 ±0.2
TOPAZ	15.4 ±0.2	14.4 ±0.2
ZVONKOVÉ	13.5 ±0.1	14.5 ±0.2
FLORINA	13.6 ±0.1	13.7 ±0.1

**Table 2** Dry matter content (%) of carrots grown under organic and integrated systems.

Cultivar	Density of plants (1000/ha)	Farming system	
		organic	integrated
AFALON F1	600	10.8 ±0.8	14.4 ±0.8
AFALON F1	900	10.7 ±0.8	13.5 ±0.4
CORTINA F1	600	12.9 ±0.5	11.5 ±0.8
CORTINA F1	900	13.6 ±0.8	13.4 ±0.8

**Table 3** Carbohydrates content of apples grown under organic and integrated systems.

Cultivar	Sucrose (g.kg <sup>-1</sup> )		Glucose (g.kg <sup>-1</sup> )		Fructose (g.kg <sup>-1</sup> )	
	integrated	organic	integrated	organic	integrated	organic
IDARED	1.14 ±0.06	1.24 ± .08	12.88 ±0.75	18.01 ±1.66	76.81 ±2.60	87.30 ±9.83
MELROSE	0.45 ±0.04	0.43 ±0.05	29.82 ±0.75	35.89 ±0.81	84.52 ±1.88	112.20 ±11.01
ONTARIO	0.14 ±0.01	0.04 ±0.01	12.03 ±0.48	8.36 ±0.81	88.46 ±14.06	78.89 ±2.12
ŠAMPION	0.47 ±0.02	0.79 ±0.05	9.84 ±1.48	25.69 ±0.59	99.29 ±2.74	133.01 ±4.87
TOPAZ	2.37 ±0.05	1.85 ±0.22	6.18 ±0.44	2.15 ±0.37	65.59 ±0.20	60.97 ±1.24
ZVONKOVÉ	0.55 ±0.01	0.26 ±0.02	6.01 ±0.60	7.48 ±0.83	59.21 ±2.60	85.17 ±2.14
FLORINA	1.62 ±0.10	0.42 ±0.01	16.24 ±0.14	5.34 ±0.65	74.08 ±2.05	66.44 ±2.96

**Table 4** Carbohydrates content of carrots grown under organic and integrated systems.

Cultivar (Density)*	Sucrose (g.kg <sup>-1</sup> )		Glucose (g.kg <sup>-1</sup> )		Fructose (g.kg <sup>-1</sup> )	
	integrated	organic	integrated	organic	integrated	organic
AFALON F1 (600)	0.44 ±0.09	0.94 ±0.41	6.65 ±2.76	14.45 ±4.24	8.98 ±1.72	11.40 ±4.65
AFALON F1 (900)	0.31 ±0.05	0.26 ±0.02	6.65 ±1.08	7.07 ±0.58	9.93 ±1.88	11.73 ±1.37
CORTINA F1 (600)	0.18 ±0.12	0.41 ±0.05	2.51 ±0.47	6.34 ±0.46	5.49 ±0.99	8.57 ±0.80
CORTINA F1 (900)	0.44 ±0.11	0.54 ±0.09	4.31 ±0.96	5.08 ±0.66	5.33 ±1.59	6.19 ±1.88

\* Density of plants (thousands per hectare)

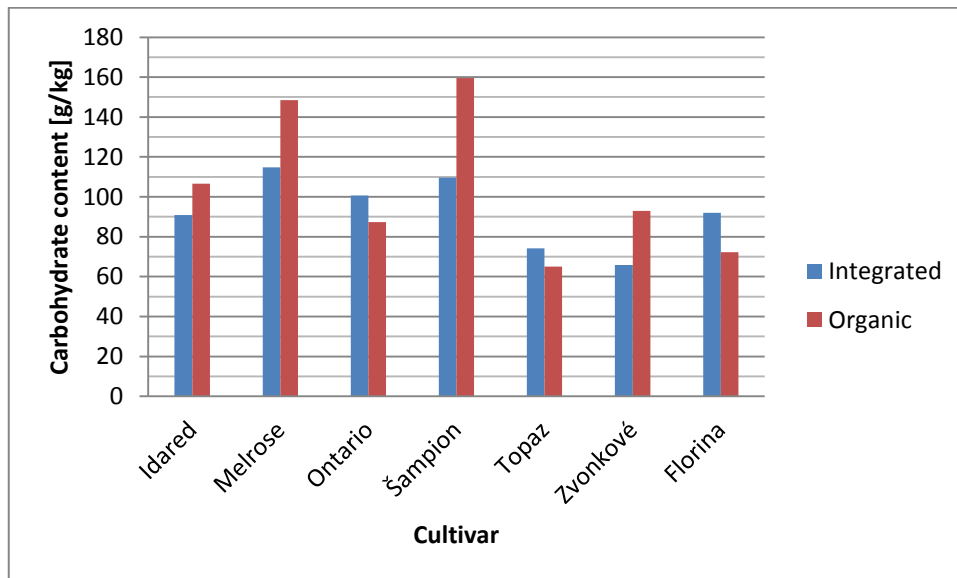


Figure 1 Total carbohydrate content of apples grown under organic and integrated systems

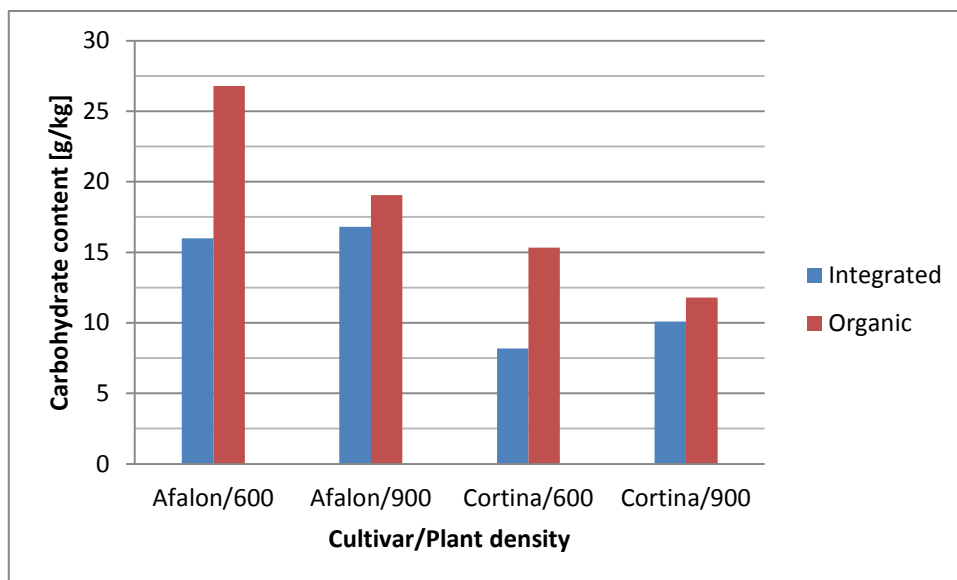


Figure 2 Total carbohydrate content of carrots grown under organic and integrated systems

Comparing all types of carrots, fructose was the most represented carbohydrate followed by glucose and sucrose, which corresponds with the same representation as in the case of analysed apples. Unlike apples, where the fructose content is markedly higher than the glucose content, the content of these monosaccharides in carrots is more or less comparable.

## DISCUSSION

The results of dry matter content in the varieties of apples (Table 1) were slightly lower than in Kopec (1998), but generally in line with Nour et al. (2010) and Kourimska et al. (2013). There were statistically significant differences between the dry matter content in organic and integrated apples ( $p < 0.0001$ ) as well as between the dry matter content and cultivar ( $p < 0.0001$ ). Apples from organic farming had, on average, a higher amount of dry matter than apples from integrated system, which is in line

with findings of Bertazza et al. (2010) who found a significantly higher content of dry matter in organic “Golden Delicious” apples. But this tendency was not observed in all cultivars. “Ontario” and “Topaz” apples showed the opposite trend. The joint effect of cultivar and farming method was confirmed by the significant interaction of these two factors ( $p < 0.0001$ ).

The values of the dry matter content of carrots (Table 2) are consistent with the literature (Vogel, 1996; Kopec, 1998). No significant differences between the different density of plants per hectare (600 or 900 thousand) ( $p = 0.1704$ ) or between cultivars ( $p = 0.1233$ ) were found, but the interaction between these two factors was significant ( $p = 0.0062$ ). Carrots from integrated farming showed a significantly ( $p = 0.0004$ ) higher amount of dry matter content (13.20%) compared to the organic carrots (12.01%). The interaction between cultivars and farming systems was also significant ( $p < 0.0001$ ).

The measured concentrations of carbohydrate content in apples (Table 3) correspond with the values given by **Kopec (1998)** and **Ma et al. (2014)**. Significant differences between the farming systems as well as between cultivars were calculated comparing the content of sucrose, glucose and fructose in all seven organic and non-organic samples. The calculated  $p$ -values were in all cases below the significance level  $\alpha = 0.05$  (they were even less than 0.0001), except the effect of farming systems and glucose content where it was 0.0001. The  $p$ -values were also less than 0.0001 for all interactions between cultivar and farming system. The content of prevailing carbohydrates (fructose and glucose) was reasonably higher in organic apples “Idared”, “Melrose”, “Šampion” and “Zvonkové”, which is consistent with **Bertazza et al. (2010)** who also detected higher contents of monosaccharides in organic fruit. On the other hand, **Prugar (2000)** found no significant differences in carbohydrate content between organic and non-organic systems. This could be supported by our results from cultivars “Ontario”, “Topaz” and “Florina” where the contents of glucose and fructose showed an even higher content in the case of integrated systems. These controversial tendencies support the importance of many factors affecting the carbohydrate content in apples.

The carbohydrate content in carrots (Table 4) was slightly lower than in literature sources (**Vogel, 1996; Kopec, 1998; Soria et al.; 2009**), but it could vary depending on the cultivar (**Cefola et al. 2012**). According to **Bufler (2013)** starch content is a key reserve of carbohydrates in carrot. The most represented sugars are fructose and glucose. All bio cultivars of carrots had higher concentrations of carbohydrates than integrated samples. Statistically significant differences were calculated for sucrose ( $p = 0.0083$ ), glucose ( $p = 0.0003$ ) and fructose ( $p = 0.0303$ ). **Hogstad et al. (1997)** indicated that the amount of fertilizer used is one of the most important factors for sugar content in carrots. Carrots grown with no fertilizer and carrots fertilized with 40 - 80 kg nitrogen ha<sup>-1</sup> as mineral fertilizer or 20 - 72 t.ha<sup>-1</sup> of organic fertilizer contained more total sugars compared with carrots fertilized with 100 - 192 kg nitrogen ha<sup>-1</sup> as mineral fertilizer. Carrots in our experiment were fertilized by a slightly higher dose of nitrogen in the case of integrated samples (80 kg. ha<sup>-1</sup>) compared to samples from organic farming production (54 kg.ha<sup>-1</sup>). The differences, however, are in the form and thus the availability of nitrogen. The organic form of nitrogen prevails in Organica fertilizer and it must first be mineralized to the form acceptable for plants. In this way, a steady supply of lower levels of nitrogen for a longer period is ensured, which may have a significant influence on carbohydrates' formation and levels.

Different densities of plants also affected the carbohydrate content in carrots, but significant difference was calculated only in the case of glucose ( $p = 0.0373$ ). The cultivar was a very important factor for the final sugars content. “Aftalon F1” showed higher concentration of monosaccharides compared to “Cortina F1” ( $p = 0.0001$ ) for fructose and  $p < 0.0001$  for glucose). No significant difference was found for sucrose ( $p = 0.1657$ ) but the level of this disaccharide is reasonably lower and

less important than levels of monosaccharides. **Seljasen et al. (2013)** also reported that the genetic factor shows the highest impact on quality variables in carrots. But they also found that climate-related factors may cause a difference of up to 82% for total sugars. The combined action of multiple factors is also supported by significant interactions calculated between variety and density ( $p < 0.0001$  for sucrose and  $p = 0.0176$  for glucose), as well as the density of plants and growing conditions ( $p = 0.0186$  for sucrose and  $p = 0.0026$  for glucose).

Our findings from apples and carrots analyses are not generally in line with **Prugar (2000)** who found no significant differences between products from organic and conventional growing systems in the dry matter content or total carbohydrates, but it must be stated that the problem is more complex and the effect of other factors, such as cultivar or density of plants, were also very important. This corresponds with **Nagy et al. (2012)** who stated that, in the case of apples, their sugar content was more affected by cultivars than by production systems. **Róth et al. (2007)** and **Bordeleau (2002)** reported the same conclusions. They agree that the quality is affected by many other factors such as cultivar, climate, soil type and subsequent storage conditions. These parameters often have a greater impact than the production method (**Bordeleau, 2002**).

## CONCLUSION

Many statistically significant differences were found comparing carbohydrates and dry matter content of apples from organic and integrated farming systems, but the tendencies were not the same for all cultivars. Some differences were also calculated between organic and non-organic carrots. Samples from integrated farming system showed significantly higher dry matter content than organic carrots. Bio cultivars of carrots had higher concentrations of sucrose, glucose and fructose than integrated samples. Our findings showed that farming systems could affect the composition of apples and carrots, but also some other factors like cultivar or density of plants significantly influence their quality parameters.

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