A Comparative Study of Quality Attributes of Integrated and Organically Produced Apple Fruit

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Abstract

The importance of food safety is growing everywhere in the world, thus also environment friendly growing systems come more and more into focus. Organic production in particular claims at achieving better quality fruit and consumers are willing to pay a premium price for this. However, there is little scientific evidence to backup these claims. The objective of this research is to find out how different production systems (integrated, organic) affect the external aspect, texture and flavor of apples. Six apple orchards were selected (3 organic and 3 integrated) in 3 different growing regions of Belgium as a basis of current experiment. Texture, soluble solid content, taste parameters (sugars: sorbitol, sucrose, glucose, fructose and acids: malic acid, quinic acid) and the aroma profile of apples have been studied at harvest and after two weeks of storage under shelf-life conditions. Apples were picked at the same maturity for excluding the effect of different harvest maturity. After shelf-life stiffness and firmness mostly remained higher in the integrated apples compared to the organic ones, while the soluble solid content was slightly higher in the organic apples. Results showed no considerable difference in the taste of apples coming from different growing regions or different production systems. When examining the aroma profiles of apples, differences were found between fresh apples and those stored two weeks under shelf-life conditions, and also between apples coming from different production system.

INTRODUCTION

Nowadays consumers pay a lot of attention to healthy nutrition, and its importance is growing everywhere in the world. Integrated fruit production is defined as the economical production of high quality fruit, giving priority to ecologically safer methods, hereby minimizing the undesirable side effects and use of agrochemicals. This system is now the most widely used production system in many countries including Belgium. Organic production essentially excludes the use of many inputs associated with modern farming, most notably synthetic pesticides and fertilizers.

Besides the presumed health properties, both systems claim to yield products which have a better internal quality (flavor, texture, vitamins). However, surprisingly little research has been carried out to validate these claims. One of the few studies were conducted by Weibel et al. (1999) who examined ‘Golden Delicious’ apples from organic and integrated (IP) orchards in Switzerland. Fruits from both production systems had many similar characteristics but, compared with fruits from IP plots, organically produced fruits were firmer, had a higher technical quality index, had higher phosphorus, fiber and phenolic compound contents (particularly flavonoids), and higher scores in the taste panel test. However, as integrated and organic production systems may vary between different countries, it is not clear whether these results can be extrapolated to other countries, or even to other cultivars. Finally, little is known about the biochemical and histological properties which are responsible for the observed differences. Previous research showed differences between the two growing systems in their postharvest behavior (Róth et al., 2001a, 2001b, 2004), but these differences were mainly due to different ripening stages at harvest. Thus in recent experiment special attantion was paid on harvesting all apples at close to the same ripening stage. The objective of our research was to examine whether there is a difference in the quality (texture, taste and aroma) and postharvest behavior of apples coming from integrated versus organic orchards.

MATERIALS AND METHODS

Raw Material

Six apple (*Malus x domestica* 'Jonagold') orchards have been chosen (3 organic and 3 integrated) in 3 different production regions of Belgium to provide raw material for the experiment. Orchards were selected in such a way that the organic-integrated pairs are located close to each other so that the effect of microclimate and soil type can be minimized.

As the maturity stage of the fruit at harvest has a great influence on the postharvest quality during storage a maturity stage indicator − the Streif-index − was monitored in the last two weeks before harvest. According to the Streif-index all apples were picked around their optimal maturity for storage.

From every orchard 180 healthy apples were selected and numbered soon after harvest. 60 apples per orchards were stored under controlled atmosphere conditions (1 °C, 1 kPa O_2, 2.5 kPa CO_2), 60 apples were stored under normal air (1 °C, 21 kPa O_2, 0.03 kPa CO_2), 30 apples were kept at 20°C simulating shelf-life conditions, while 30 apples per orchards were used as raw material for the analysis at harvest. 10 apples per batch were used for determining the Streif-index at harvest.

In all measurements apples were treated as individuals thus all measured parameters are known for each apple.

Methods

1. Stiffness. The acoustic stiffness (Schotte et al., 1999) of all marked apples has been measured using the Aweta acoustic firmness sensor (Aweta DFT, Version 0.0.0.7) to describe the initial stiffness of the apples. Further the stiffness of 20 apples were measured at each sampling time (harvest and after shelf-life). Five parallel measurements were done on each apple at their equator and the mean was used to characterise the stiffness of the samples.

2. Firmness. The Magness-Taylor firmness was measured by using the Stable Micro Systems Texture Analyser (TA-XT2) with a cylindrical probe (11 mm diameter). The maximum force needed to penetrate the flesh over a distance of 8 mm at a speed of 8 mm/s was measured at two opposite sites on the equator of the fruit. The apple was peeled at the spot of penetration before the measurement. Apples were measured at harvest and after shelf-life.

3. Soluble Solid Content. The juice that was released by the firmness test was used to measure the soluble solids with a digital refractometer (Atago Co. Ltd., Tokyo, Japan) and expressed as %Brix.

4. Sugar and Acid Content. Taste components of the apples have been analyzed using HPLC (RID detector for sugars and diode array detector for acids). The most important taste components in apples are sugars (glucose, fructose and sucrose) and organic acids (malic and citric acid). Immediately after measuring the MT-firmness and soluble solid content, samples have been prepared and then frozen in liquid N_2 and stored at -80°C for later taste- and aroma analysis from the individual apples. Frozen powder of apple tissue was extracted 3 times using ethanol, then dried and stored frozen (-20 °C). Water-diluted samples were made from this frozen extract and analyzed with HPLC (Agilent 1100 Series) using an Aminex® Resin Based column (HPX-87C, 300mm x 7.8mm) and water mobile phase for analysis of sugars (sorbitol, sucrose, glucose and fructose), while an Alltech Prevail Org. Acid 5u column (250mm x 4.6mm) and KH_2PO_4-mobile phase (pH=2.5) was used for analyzing the organic acids (malic and quinic acid).

5. Aroma Profile. The aroma of apples was measured objectively by sampling the apple headspace by solid-phase micro-extraction (SPME, Supelco Co., Bellefonte, USA) using a fiber coated with a 65 µm layer of PDMS/DVB (preconditioned at 250°C for 1 h), and after 14 minutes extraction the volatiles were subsequently desorbed during 60 s at 250°C into the glass-lined splitless injection port of a GC (6980N, Agilent Technologies), then the volatiles were transferred to an MS (5973 Network Mass Selective detector, Agilent Technologies) using an undeactivated, fused silica capillary column (ID: 0.10mm, length: 10m), where the mass spectra was collected over an m/z range of 10-350. Headspace Fingerprinting Mass Spectrometry (HFMS) is an innovative and rapid method in which the headspace is injected directly in the source of the mass spectrometer without prior gas chromatographic separation. The aim of the research was to reduce the overall time used for a single analysis to few minutes and obtain a mass spectrometric "fingerprint" which can characterize the aroma profile of the apple. This fingerprint has been used further for discrimination purposes. The technique has been used successfully in the laboratory before for rapid profiling of apple and tomato aroma (Saevels et al., 2003; Berna et al., 2004). To reduce the required time of measurement it was decided to use juice from the apples as the steady state of the headspace can be established faster in the 20ml vial above the juice than in case of measuring an intact apple (Saevels et al., 2003). By preparing the juice attention has to be paid on the prevention of volatiles from oxidation. In a preliminary experiment we evaluated saturated NaCl (Augusto et al., 2000; Fallik et al., 2001; Bai et al, 2002, 2003), saturated $CaCl_2$ (Speirs et al., 1998) and ascorbic acid (Kato et al., 2003) for preventing the juice from oxidation. Adding saturated salt solutions to the juice causes enzymes to precipitate and enhances the liberation of aroma compounds into the headspace. Saturated NaCl gave the best result and has been used further on. To get a less viscous sample also a certain amount of water needs to be added to the apple pieces while preparing the juice-sample. For sample preparation, the method described by Bai et al., 2003 has been followed. As a GC/MS system is used but no separation is required, fast transfer of the volatile components from the injection oven to the source of the MS is required. After evaluating different columns, an undeactivated, fused silica capillary column (ID: 0.10mm, length: 10m) has been chosen for the analysis.

6. Statistical Evaluation

A general linear model and Tukey's Studentized Range Test was used to evaluate data of basic parameters by the SAS System 8.0 program (SAS Institute, Heidelberg, Germany). Principal component analysis (PCA), using the Unscrambler software (Version 6.11b, CAMO AS Trondheim, Norway) has been used to discriminate between production methods and growing regions.

RESULTS AND DISCUSSION

Basic Parameters

Differences between the firmness, soluble solid content (SSC), stiffness and initial stiffness ($stiffness_0$) of samples were analyzed by using Tukey's Studentized Range Test (SAS System 8.0 program) on the means. The mean values of basic parameters can be seen in Table 1. Means with the same letter are not significantly different. Apples from different growing regions and different production systems did not differ in texture and soluble solid content at harvest. According to the results of the shelf life experiment it was observed that the stiffness decreased considerably during shelf-life, while the decrease in firmness was not considerable. Results also showed that the stiffness and firmness mostly remained higher in the integrated apple than in the organic ones, while the soluble solid content was slightly higher in the organic apples.

Taste Profile

Due to the possible micro-climate and soil differences at the different growing regions, a difference in internal parameters was expected. However, no considerable regional effect on the taste parameters (sugar- and acid-content) was found. Figure 1. shows the score plot of PCA on the taste components of apples, at harvest, where no separation between growing regions or production systems can be seen. The first principal component explains 78%, while the second principal component explains 17% of the variability. The score plot was based on the covariance matrix of the taste parameters. Figure 2 shows the loading plot of the same PCA. It can be seen from Figure 2 that fructose, sucrose and glucose are the most important taste parameters according to their higher concentrations, while sorbitol and the studied acids play less important role in distinguishing between the samples. The PCA of apples after shelf-life showed the same, like at harvest.

Aroma Profile

In Figure 3 the PCA score plot of aroma attributes is shown based on all apples, whose aroma profile has been examined. The first two principal components explain almost all the variability. The score plot was based on the covariance matrix of the aroma variables. The variables were calculated by taking the relative abundance of each the mass to charge ratio. Calculating the relative data, the differences due to the area of the peak (thus the absolute concentration of aroma volatile) can be excluded, as the ratio between aroma components is much more informative for discriminate between different treatments. There is clear separation between the apples coming from organic and integrated production system. All organic samples are very close to each other, irrespective of the region, although some separation can be seen between the fresh apples and those stored two weeks under shelf-life conditions. Apples coming from integrated orchards differ more from each other than the organic ones, but there is still a clear separation between fresh apples and those has been stored under shelf-life conditions. No regional effect can be recognized neither in case of integrated apples. Difference between organic and integrated apples cannot be due to the size of apples as weights of apples (Table 2) were not significantly different.

Summarizing our results it can be stated that there seems to be an effect of the production system on the quality of apples, especially on the aroma volatiles, while taste parameters are not affected so much by the different growing methods. Considering the measured physical parameters, stiffness and firmness mostly remained higher in the integrated apples compared to the organic ones, while the soluble solid content was slightly higher in the organic apples after two weeks under shelf-life conditions. No considerable regional effect has been experienced when studying the quality of apples, maybe due to the small differences between orchards in climate and soil parameters.
Further experiments are being carried out to have a more complete view on the studied topic.

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Tables

Table 1: Mean values of physical parameters and their differences (95% significance level)

			Firmness (kg)	SSC (%)	Stiffness ($s^{-2}*kg^{2/3}$)	$Stiffness_0$ ($s^{-2}*kg^{2/3}$)
Harvest	Orchard I	organic	7,11 bc	13,52 abc	29,25 b	29,25 bc
		integrated	7,37 ab	13,32 bcd	29,31 b	29,31 bc
	Orchard II	organic	7,93 a	13,44 abc	32,72 a	32,72 a
		integrated	7,37 abc	12,79 cd	30,31 b	30,31 b
	Orchard III	organic	7,35 abc	12,32 d	29,86 b	29,86 bc
		integrated	7,41 abc	12,40 d	29,85 b	29,85 bc
After shelf-life	Orchard I	organic	6,98 c	13,81 ab	18,05 d	29,33 bc
		integrated	7,40 abc	13,54 abc	23,22 c	29,20 bc
	Orchard II	organic	7,76 a	14,12 a	19,02 d	32,92 a
		integrated	7,40 abc	13,44 abc	22,61 c	28,89 bc
	Orchard III	organic	6,94 c	12,87 bcd	22,34 c	28,32 c
		integrated	7,53 abc	13,79 ab	18,61 d	29,38 bc

Table 2: Mean values of weights of apples and their standard errors

			Means of weight (g)	Standard errors of means
Harvest	Orchard I	organic	234,90 a	13,74
		integrated	249,60 a	9,02
	Orchard II	organic	226,10 a	6,20
		integrated	215,05 a	7,60
	Orchard III	organic	217,00 a	7.34
		integrated	226,61 a	10.01
After shelf-life	Orchard I	organic	226,65 a	13,42
		integrated	245,50 a	8,77
	Orchard II	organic	217,85 a	6,13
		integrated	211,65 a	7,49
	Orchard III	organic	213,70 a	7,20
		integrated	219,39 a	9,89

Figures

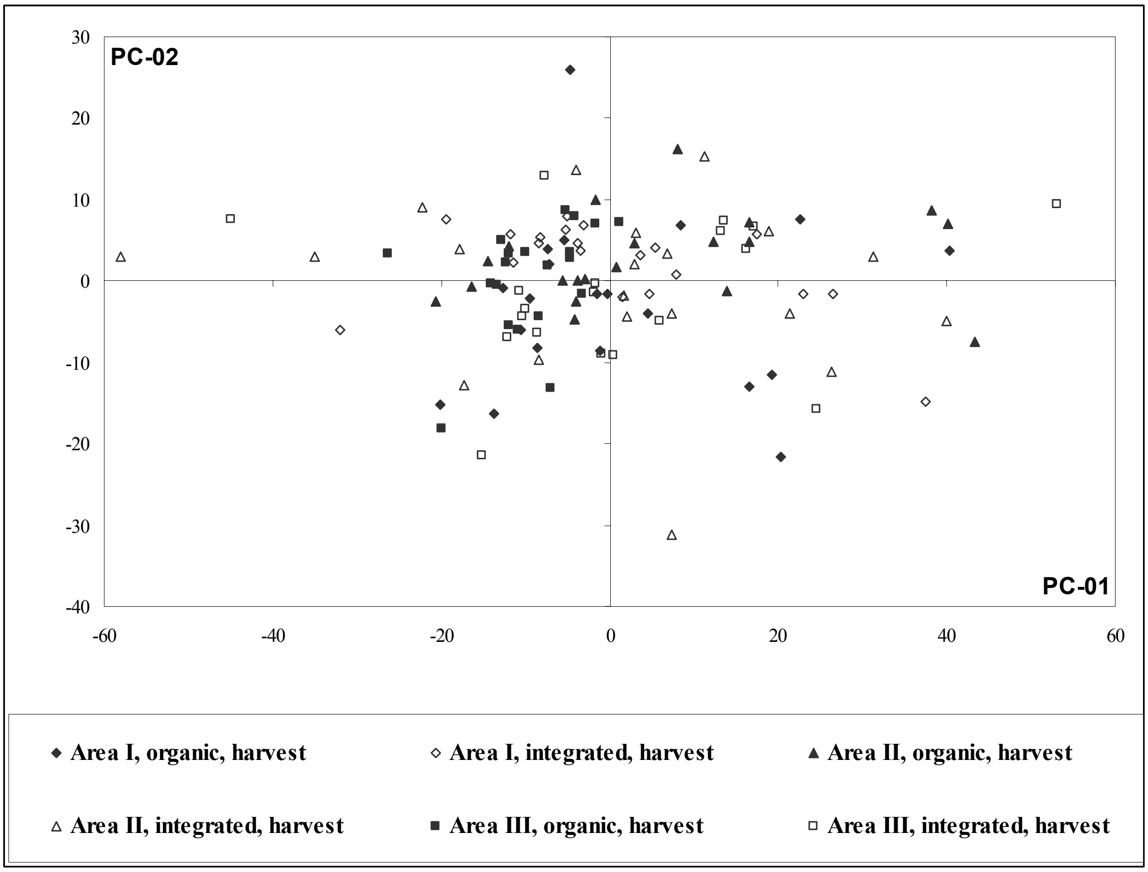

Fig. 1: Score plot of PCA on the taste components of apples, at harvest

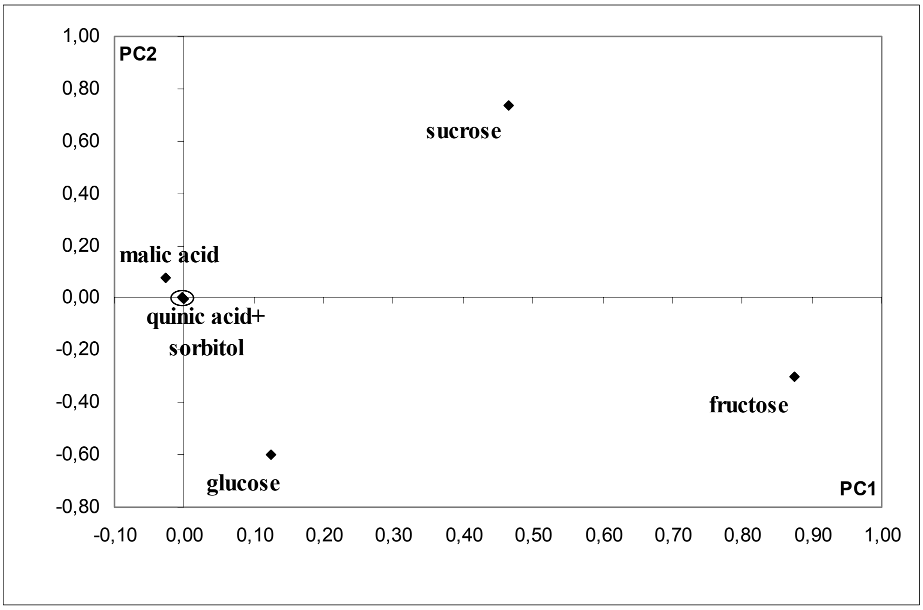

Fig. 2: Loading plot of the PCA on the taste components of apples, at harvest

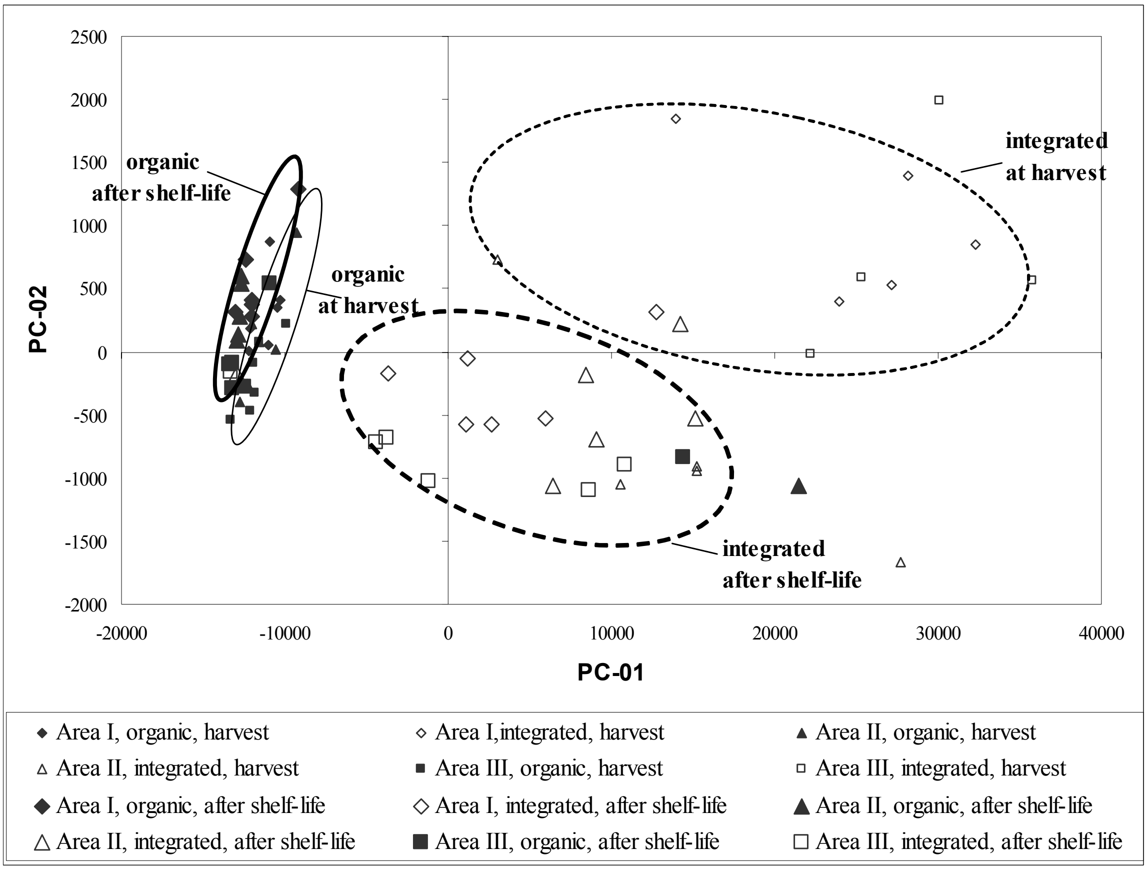

Fig. 3: Score plot of PCA on the aroma profiles of apples

Etude Comparative des Attributs de Qualité de Pommes Issues de Production Fruitière Intégrée et d'Arboriculture Biologique

Mots-clés *: système de production, chromatographie liquide haute performance (HPLC), chromatographie en phase gazeuse / spectrométrie de masse (GC/MS), profil aromatique, saveur.*

Résumé

L'importance de la sécurité des aliments s'accroît partout dans le monde, et les systèmes de production respectueux de l'environnement s'améliorent progressivement. La production biologique de fruits revendique particulièrement l'amélioration des qualités et les consommateurs semblent prêts à payer pour ce type de produits. Cependant, il existe encore peu de preuves scientifiques à l'appui de l'argument d'une qualité supérieure. L'objectif de cette recherche était donc de mettre en évidence en quoi différents systèmes de production (production fruitière intégrée ou PFI et arboriculture biologique) modifient l'aspect extérieur, la texture et la qualité organoleptique des pommes. Six vergers ont été choisis (3 vergers en bio et 3 vergers en PFI) dans 3 régions de production en Belgique, pour fournir les fruits de la présente approche expérimentale. La texture, la teneur en matière sèche, les composés liés à la saveur (sucres solubles d'une part : sorbitol, saccharose, glucose, fructose ; acides malique et quinique, d'autre part) ainsi que le profil aromatique des pommes ont été étudiés à la récolte et après 2 semaines de conservation à température ambiante. Les pommes ont été prélevées au même stade de maturation pour éviter le biais de stades de maturité différents. Après deux semaines de conservation, la dureté et la fermeté demeurent globalement plus élevées pour les pommes issues de PFI que pour les pommes bio, tandis que la teneur en matière sèche soluble est au contraire supérieure pour les fruits issus d'arboriculture biologique. Les résultats relatifs à la saveur n'ont pas montré de différences nettes en fonction des régions d'origine ou des systèmes de production. L'examen des profils aromatiques des pommes a révélé des différences entre les pommes fraîchement récoltées et les pommes conservées 2 semaines en conditions ambiantes, ainsi qu'entre pommes issues de différents systèmes de production.