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Influence of processing on the quality of pomaceas juice (*Pyrus communis* and *Malus domestica*)

Andressa Schaia Rocha, Acácio Antonio Ferreira Zielinski, Suelen Ávila, Alessandro Nogueira and Gilvan Wosiacki*

*Departamento de Engenharia de Alimentos, Ciências Agrárias e Tecnologia, Universidade Estadual de Ponta Grossa, Av. Carlos Cavalcanti, 4748, 84035-350, Uvaranas, Ponta Grossa, Paraná, Brazil. *Author for correspondence. E-mail: wosiacki@uol.com.br*

ABSTRACT. Pear (*Pyrus communis*), which is intensively cultivated in subtropical and temperate climates, has recently attained the 3rd position in the world fruit ranking, just after apple and peach. This fruit exhibits certain similarities to apple with respect to the pulp, but pear is used as a raw material only when apple is no longer available, which suggests that the same technology line may be utilized. Both fruits do have processing compatibilities, and it is permissible to add pear juice to apple juice at levels defined by law. Quality indicators, such as pH, total acidity, total phenolic compounds and antioxidant activity were used. The simple sugar analysis clearly defines fructose as the main component in pear juice, and lower figures were found when enzymatic processing was used. Color intensity measured instrumentally was much greater in pear juice with all processing methods and in apple juice when an enzymatic method was used. The results clearly indicate proper ways of processing pear and apple, aiming to have better products, as the grinding and extraction processing steps surely affect the fruit juice quality.

Keywords: juice processing, apple, pear, quality profile.

Influência do processamento na qualidade do suco de pomáceas (*Pyrus communis* e *Malus domestica*)

RESUMO. A pera (*Pyrus communis*), terceira fruta cultivada em climas temperados e subtropicais e somente superada pela maçã e o pêssego, guardam semelhanças físicas e químicas enquanto pomaceas. Somente há processamento de pera na falta de maçã enquanto matéria prima, o que sugere que a mesma linha tecnológica possa ser usada. São compatíveis, sendo permitida a adição de suco de pera no suco de maçã pela legislação. Os indicadores de qualidade mais acentuados no suco de pera foram acidez, o teor de compostos fenólicos totais e a capacidade antioxidante. Na distribuição de açúcares os teores de frutose foram expressivamente mais acentuados no suco de pera, com menores valores quando era empregado o método enzimático. A intensidade de cor, determinada instrumentalmente, foi mais expressiva no suco de pera, em especial no despolpamento, enquanto que no de maçã, no enzimático. Os resultados indicam de forma clara que a pera se comporta como matéria-prima aos processos com aptidão ao processamento de maçã, todavia cada fruta tem o seu próprio perfil de qualidade. Os resultados claramente apontam para os procedimentos mais adequados para obter bons produtos eis que as etapas de moagem e a de extração seguramente contribuem para a modificação da qualidade dos sucos de pera e de maçã.

Palavras-chave: processamento de suco, maçã, pera, perfil de qualidade.

Introduction

According to the Food and Agricultural Organization (FAOSTAT, 2011), at the beginning of the 21st century, Brazilian apple production, supported by a national program intended to supply both the domestic market and the emergent international business with high-quality apples, reached the reported level of 1,000,000 metric tons (WOSIACKI et al., 2002). Pear currently represents the 3rd most common fruit grown in subtropical areas, although there is not an equilibrium of production vs. consumption, as 20,000 tons are cultivated in Brazil for a domestic consumption of approximately 155,000 tons, which means that more than 85% of the national supply of this expensive fruit is imported from the occidental countries of Europe (COUTINHO et al., 2003; FIORAVANÇO, 2007).

The culture of pears in Brazil did not receive any special attention to promote its development, but the industrial parks used for apple processing provide some facilities for the raw material and the storage of processed drinks. There are no attempts to research further the protocols for various noble products, such as *Liqueur de poire* (EL-ZOGHBI; SHEHATA, 1997; PARK et al., 2001), although actual scientists involved in the subject may have good research results (NAKASU; FAORO, 2003).

If the same strategies used for apple production could be tested for pear, it could be expected that, within approximately two years, this industry would achieve similar success, conserving large amounts of money and energy. Moreover, the utilization or treatment of the industrial processing wastes should be practically the same, rendering industrial units easy to build. The consumption of pears in the domestic market is much higher than the apple consumption, which must be taken into account when considering the scale of the manufacturing process. However, this consumption could easily be higher if the fruit was supplied throughout the year, as currently, pears are seldom available in the period from August - December (NAKASU, 2003). Pears *cv* Williams and Red Williams are available during (January – July), *cv* D'Anjou (June – July), and *cv* Packham's and Triumph (August – December), mostly as retail coming from different producing countries (FIORAVANÇO, 2007).

Although pear is still considered to be an alternative crop, fruit research groups have already been mobilized to develop projects for the improvement and adaptation of varieties with partners overseas that have access to qualified human resources to synergistically accelerate the implementation of orchards with economic impact in the sector.

In general, the pear is similar to the apple, the other pomaceous fruit, and the history of both is quite similar. In temperate regions, the former fruit follows the steps of the latter in terms of technological development. Considered to be a premium beverage, pear juice can be added to increase the total soluble solids in apple juice, but only to a limited amount defined by law (NOGUEIRA et al., 2003a). Higher additions could be considered to be fraudulent; however, this phenomenon is self-controlled by the high prices of pear juice and is, in any case, easily identified by the presence of proline in pear extract but not in apple (THAVARAJAH; LOW, 2006).

The different manufacturing processes can impart several disadvantages to the product quality, and in this work, the results of a physicochemical evaluation of pear and apple juice are shown, aiming to define a quality profile using pattern recognition techniques.

Material and methods

Material

A total of 40 kg of commercial pear (*Pyrus* sp) *cv* Packham's Triumph (2010 crop season), imported from Portugal, and another sample from apple (*Malus domestica) cv* Gala (2009-2010 crop season), produced in this country, were used as the subjects. Pectinolytic enzymes were obtained from NOVO Nordisk through the office of LNF (Bento Gonçalves, Rio Grande do Sul State), its representative in Latin America. The equipment used in the experimental plan was laboratory-size.

Methods

Processing

Cold stored raw material, after careful selection to remove infected fruits, was further cleaned with tap water and sanitized with sodium hypochlorite (100 mg L^{-1}). Grinding and extraction were the processes chosen as the input variables in this study. Samples of fruits were milled with knives or a hammer mill, and the juice was extracted by mechanical or centrifugal pressure, according to the process protocol. The combinations of these input variables are characterized as conventional (knives/mechanical), decanter (hammer/combined), multiprocessor (knives/centrifuge) and enzyme technology (knives/centrifuge). Depectinization was performed using Pectinex® 100 L (3 mL hL^{-1}) in hot conditions (45ºC 60 $min.^{-1}$), and further clarification was achieved with gelatin (3 g hL^{-1}) and bentonite (40 g hL^{-1}), followed by filtration through paper (CNTP). These procedures, adapted to the laboratory, were carefully performed, respecting the theoretical and practical aspects mentioned by Birus (2001).

Analysis

The reducing and total reducing sugar were quantified with the classic colorimetric method of Somogyi (1945) as modified by Nelson (1944); glucose determination was performed using the enzymatic kit (GOD); total phenolic compounds were assessed using the Folin-Ciocalteu reagent and catechin as a standard (SINGLETON; ROSSI, 1965); antioxidant activity was determined by the methods described by Benzie and Strain (1996) and Pulido et al. (2000); total soluble solids were calculated with figures obtained in a digital refractometer and expressed as °Brix, which means g 100 g^{-1} or g 100 mL^{-1} (IAL, 2008); and the color intensity was calculated as ΣA_{440nm}, A_{520nm}, A_{600nm}, with the figures corresponding to the chromophores for phenols and anthocyanins, and turbidity (TANNER; BRUNNER; 1985). The results of the experiments were analyzed by ANOVA, to a 95% confidence level, and the differences were qualified with the differential method of TUKEY, 5% probability, with the statistical software STATISTICA 7.0 for Windows (Statsoft, INC.). The results from the experimental design were analyzed with multivariate tools in an exploratory fashion by principal component analysis (PCA/HCA) using the Pirouette software (Infometrix®) version 4.1.

Results and discussion

Major components

In Table 1, the major components of the clarified juices of pear and apple selected for the characterization of a profile for the juices are shown in relation to the methods by which they have been processed.

The total soluble solids, defined as the refractive index of the juice, including sugars, acids, polyols and others, expressed in g 100 mL^{-1} or g kg^{-1}, have been related to the degree of fruit ripeness (WILL et al., 2000; JAYASENA; CAMERON, 2008). Comparing the methods, it is possible to observe that the use of pulping yielded the highest values for soluble solids for both fruits, with 11.50 and 12.25 °Brix for pear and apple, respectively. This indicates that this method is the best one with respect to this output variable.

The acidity is related to the degree of ripeness, as are the sugar levels (JAYASENA; CAMERON, 2008), and when the acidity is calculated in terms of malic acid, as described by Czelusniak et al. (2003), it can be expressed in g 100 mL^{-1}. An acid level below 0.45 g 100 mL^{-1} indicates sweet apples, and a level above this value indicates tart apples (PAGANINI et al., 2004). All of the results obtained in this analysis had acid levels below 0.45 g 100 mL^{-1}, which means that the fruit were ripe and sweet. The pear showed higher acid levels than the apple, which can be explained by the acid composition, as pears contain citric and malic acid in equal proportion, whereas apple contains almost entirely only malic acid (HERRMANN, 2001). Citric acid is stronger than malic acid, as can be shown their respective acid dissociation constants, pK_a 3.09 and 3.40 (HERRMANN, 2001; MAHLER; CORDES, 1971). This value classifies pear as a semi-acid fruit and apple as a sweet fruit (CLAUDINO, 2009). For both fruits, when enzyme technology was used, the products were more acidic. The results obtained with centrifugation for pear and with pulping for apple did not differ significantly from those obtained by the conventional method.

The total phenolic compounds mainly comprise chlorogenic acid and its esters, which are important in the sensory characteristics of fruits due to their participation as components of the aroma, taste and color of juices and wines (CZELUSNIAK et al., 2003; NOGUEIRA et al., 2003b; WIECHETECK et al., 2005). The oxidation of these compounds due to the action of the endogenous enzyme system of oxidases in the clarification step constitutes the most frequent cause of changes in the levels (LOZANO et al., 1994; NOGUEIRA et al., 2003b). Comparing the juices, the pear showed higher phenolic content than apple in two methods (conventional and pulping), of which the pulping method demonstrated higher phenolic content (374 mg L^{-1}). In contrast, the pulping of apple yields a lower phenolic content (179 mg L^{-1}) and the enzymatic method, the largest (322 mg L^{-1}). It must be remembered that the samples were depectinized during the processing, which explains the low figures for this quality indicator.

Pear has a high antioxidant potential, even greater than that of apple, reaching values of almost twice with the enzymatic method compared others methods. The minimum antioxidant values occurred in the products obtained by the centrifuge method for pear and the pulping method for apple. There is a similarity among the products of pears processed with the conventional method, pulping and centrifuge, whereas the apple products are homogeneous (Table 1).

In the profile of simple sugars, glucose and fructose, along with the disaccharide sucrose, together constitute the main fraction of the fruits (HERRMANN, 2001; KARADENIZ; EKSI, 2002). The sugars provide sweetness to the fruit, and fructose, sucrose and glucose have relative sensorial values of 170, 100 and 70, respectively (CZELUSNIAK et al., 2003). Moreover, a good fruit juice has characteristics of brightness that are related to the refraction constant. The relative amount of these sugars in the fruits depends on the genetic background of the fruit and on the conditions of production and storage, such as the state of maturation, for example (FULEKI et al.,

Table 1. Quality characteristics of the juice of pear and apple obtained by different processes.

	*TSS (°BRIX)	MAL (g 100 mL^{-1})	TPC (mg L^{-1})	AOC (µM mL^{-1})	SUC (g 100 mL^{-1})	FRU (g 100 mL^{-1})	GLU (g 100 mL^{-1})
				Pear Juice			
I	10.25	0.33 ± 0.01^{c}	200.52 ± 13.37^{c}	1355.56 ± 75.56^{c}	0.29 ± 0.36^{b}	6.89 ± 0.49^{a}	1.13 ± 0.03^{d}
II	10.75	0.33 ± 0.02^{c}	257.88 ± 11.84^{c}	1742.22 ± 17.78^{b}	0.56 ± 0.31^{ab}	6.71 ± 0.19^{a}	1.21 ± 0.01^{c}
III	11.50	0.39 ± 0.01^{b}	374.16 ± 17.43^{a}	1742.22 ± 88.89^{b}	0.01 ± 0.50^{c}	7.58 ± 0.47^{a}	1.27 ± 0.03^{b}
IV	10.00	0.41 ± 0.00^{a}	279.39 ± 31.81^{b}	2954.80 ± 325.00^{a}	1.06 ± 2.81^{a}	5.72 ± 0.45^{b}	1.93 ± 0.09^{a}
				Apple Juice			
I	12.25	0.16 ± 0.01^{C}	212.92 ± 46.96^{B}	1168.89 ± 22.22^{B}	0.45 ± 0.31^{C}	6.90 ± 0.19^{A}	2.40 ± 0.02^{A}
II	11.50	0.20 ± 0.09^{B}	191.21 ± 23.83^{B}	840.00 ± 4.44^{C}	3.86 ± 0.18^{A}	6.67 ± 0.18^{A}	2.44 ± 0.02^{A}
III	12.25	0.20 ± 0.01^{B}	179.33 ± 0.90^{B}	484.44 ± 31.11^{D}	2.52 ± 0.38^{B}	6.74 ± 0.20^{A}	2.46 ± 0.02^{A}
IV	10.88	0.22 ± 0.06^{A}	322.58 ± 29.17^{A}	1627.91 ± 222.61^{A}	3.83 ± 0.97^{A}	5.90 ± 0.61^{B}	2.32 ± 0.16^{B}

Note: Processes: I (centrifuge), II (conventional), III (pulping) and IV (enzyme technology); TSS: total soluble solids; MAL: malic acid; TPC: total phenolic compounds; AOC: antioxidant capacity; SUC: sucrose; FRU: fructose; GLC: glucose. Values marked by the same letters are not significantly different ($p > 0.05$). Lower case letters refer to pear juice, and capital letters refer to apple juice. *Not analysis of variance.

1994; KARADENIZ; EKSI, 2002; WOSIACKI et al., 2007). The amount of fructose in apple juice shows high values and with a lower degree of dispersion than glucose, and sucrose has an intermediate level with a greater range of dispersion, with similar results for pear (CZELUSNIAK et al., 2003; HERRMANN, 2001). The proportions of fructose relative to total sugar reach 71% in apple and 85% in pear juice.

The results for the amount of sugar in the juices obtained with these four methods are shown in Table 1. It can be observed that the fructose level in both fruits is quite similar, but as apple appears to have twice as much glucose as pear, the fructose fraction in the former is much lower, less than would be expected from conventional processing methods. Despite the higher levels of fructose in pear juice, the pulping method exhibited this effect for both pear and apple. For glucose, the apple showed a higher concentration in its juice, reaching 24% in the centrifuge method; for the pear, the maximum concentration was obtained in the enzymatic method (21.55%). For sucrose, as with glucose, the apple juice showed levels well above those in the pear juice, reaching almost 30% in the conventional method compared with 13% in the pear juice processed with the enzyme method. In the pulping method for pear, the sucrose value was almost negligible, with a content of 0.11% (0.01 g 100 mL^{-1}).

The total reducing sugars comprehend both fructose and glucose in the free form and do not necessarily originate from the hydrolysis of sucrose. Comparing both fruits, apple had a higher total reducing sugar content than pear, with 12.97 g 100 mL^{-1} by the conventional method for apple compared with 8.82 g 100 mL^{-1} in the enzymatic method for pear. The conventional method and centrifugation showed a statistical relationship between their results, in contrast with the other methods, as for apple, the four methods somehow generate a statistical correlation that does not interfere much in the total sugar content.

Appearance

In Table 2 are shown the absorbance figures at specific wavelengths for the chromophore groups of the pear and apple juices.

Table 2. The color parameters according to the colorimetric analysis.

	$A_{440ηm}$	$A_{520ηm}$	$A_{600ηm}$	CI
		Pear juice		
I	0.318	0.117	0.048	0.483
II	0.841	0.426	0.215	1.482
III	2.960	1.264	0.837	5.061
IV	0.242	0.125	0.077	0.443
		Apple juice		
I	0.580	0.078	0.020	0.678
II	0.743	0.155	0.058	0.956
III	0.548	0.062	0.021	0.631
IV	1.002	0.329	0.158	1.460

Note: Processes: I (centrifuge), II (conventional), III (pulping) and IV (enzyme technology); CI (color index) = 440 ηm+520 ηm+600 ηm.

The color parameter intensity (CI) is defined as the sum of the absorbance readings, with a dimensionless character, and the amount of sugars explains the brightness of the juice, due to the refractive index. In the depectinization step, the color intensity is markedly changed compared with the raw juice: at the beginning, the browning polyphenolic compounds adhere to the chemical structure, darkening the pectin molecule. At the end, pectinase removes the degraded pectin, and the clear juice has a peculiar brightness. Concerning the methods, for the pear, the pulping presented problems with brightness because it is not easy to obtain a clear juice, in contrast to the apple, which shows the best results (0.631). The enzymatic method showed the clearest juice for pear, with a value of 0.443. In general, pear juice exhibited higher clarity and brightness compared with apple juice. The difference in the levels between the methods may be due to the degree of exposure to oxygen of the product, together with the enzymatic reaction of polyphenol oxidases (PPOs). Situations particularly favorable for oxidation occur in the steps of grinding and mechanical extraction of the juice, when the juice comes in contact with the air, as well as in the clarification at 45°C and in the filtration, when part of the juice interacts with cellulose and heat treatment for the stabilization of the product.

Exploratory procedure

Data pre-processing was performed to assign equivalent scores to the levels of compounds present in the samples (FERREIRA et al., 2002). Thus, the results were auto-scaled before they were subjected to principal component analysis (PCA). PC1 explained 56.22% of the total variance in the data set, whereas PC2 explained 18.13%. The cumulative explained variance for each additional PC is shown in Figure 1(C). According to Hossain et al. (2011), PC1 is more generally correlated with the variables than is PC2 because the PCs are extracted successively, each one accounting for as much of the remaining variance as possible. In Figure 1(A), the positions of the PCs as discrete variables are shown by a simple scatter plot, and in Figure 1(B), they are arranged as continuous variables. In the association of the *scores* and *loadings* plots, as shown in Figures 1 (A and B), it was possible to suggest reasons for the locations of the juices on the basis of their chemical composition patterns. First, considering the relative position of the *eigenvectors* I (centrifuge), II (conventional), III (pulping) and IV (enzyme technology) for pear (black circles) and apple (black squares), it was possible to verify the separation into three groups. For pear samples I, II and III, a group was observed on the left with higher levels of fructose and color index. In the right positive quadrant, samples I, II and III of the apple were observed, with higher levels of malic acid, glucose, sucrose and total phenolic compounds.

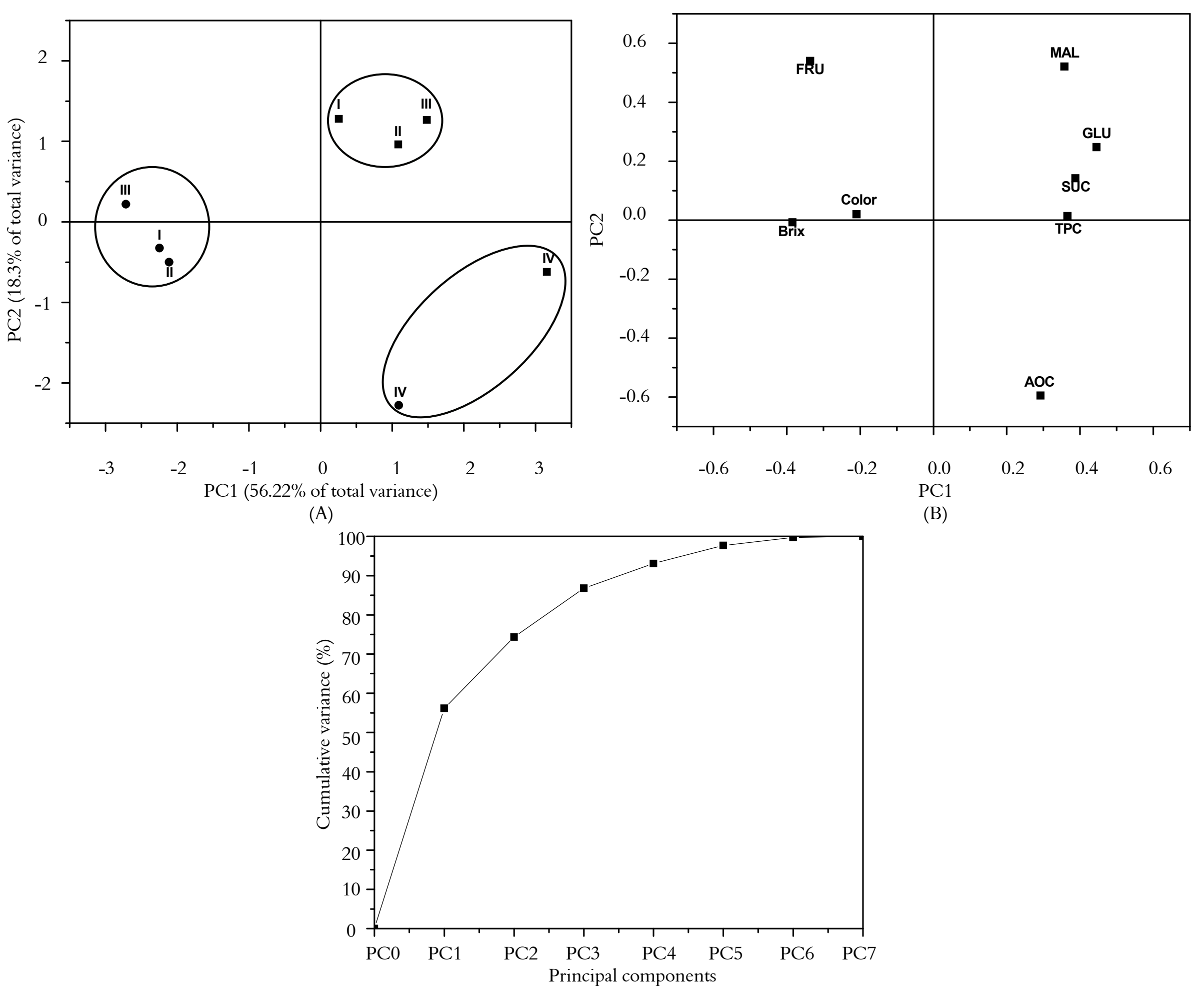

Figure 1. Principal component analysis (PCA) plots. (A) PCA *scores* plot; (B) *loadings* plots; (C) cumulative variance. Processes: I (centrifuge), II (conventional), III (pulping) and IV (enzyme technology); (●) pear juice; (■) apple juice. FRU: fructose, GLU: glucose, SUC: sucrose, MAL: malic acid, TPC: total phenolic compounds, AOC: antioxidant capacity.

The right negative quadrant held a group for the apple and pear samples obtained with enzyme technology, which had little in common with the other samples; these products have higher levels of phenolic compounds and high antioxidant activity. Pennington and Fisher (2009) used PCA to perform a classification of fruits and vegetables. These classifications were based on physical and chemical characteristics, and Vieira et al. (2011) used PCA to produce a standard approach to classify the chemical composition of 24 different Brazilian apple juices based on the Fuji and Gala varieties.

The results obtained by Hierarchical Cluster Analysis (HCA) are shown in the form of a dendrogram (Figure 2), although an exploratory data technique that used a clustering algorithm was effective in the confirmation of the groupings that emerged from the Principal Component Analysis. The samples were grouped in terms of their similarity; at a degree of 45%, the existence of three groups was indicated, referring to the four processing methods used for pears and apples and separating the enzymatic method from the others. This dendrogram confirms the relationship of the input variables of the processes and shows that two different fruits behave similarly to each other, but in different ways, leading to two distinct types of product, whereas the enzyme technology differs from the others, leading to a group in which the two products bear less resemblance to each other.

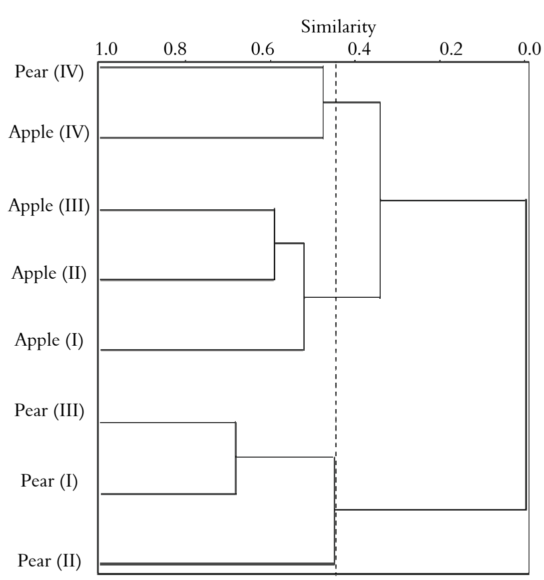

Figure 2. Dendrogram of Hierarchical Cluster Analysis (HCA). Processes: I (centrifuge), II (conventional), III (pulping) and IV (enzyme technology).

Conclusion

The pear juices showed higher acid levels, more bitterness and more antioxidant activity than the apple juices, which were sweeter and with more intense color. The pear, as a raw material, can be processed by the same methods used for apple, except with respect to pulping, the product of which consists of a dark mass (pulp) due to oxidation. The quality of the juices confirms that both raw materials can use the same line process with the modification of a few parameters. The pulping process is not suitable unless the product is also centrifuged, as it results in juices with reduced color intensity.

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