JAP&T TPA-Timişoara

Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2017, *23* (2), 104-109

Journal of Agroalimentary Processes and Technologies

Obtaining of apple vinegar with improved antioxidant function by dried fruit addition

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Received: 23 May 2017; Accepted: 30 June 2017

Abstract

This paper describes both the obtaining of apple vinegar as well as the improving its antioxidant function by addition of dried fruit with high level of bioactive compounds. Apple vinegar was prepared in laboratory conditions by acetic fermentation of apple marc following a traditional procedure used in small-scale systems or in home conditions. In order to prepare function-enhanced apple vinegar different dried fruit and mixtures of dried fruit have been added to vinegar in a proportion of 5% (w/v). In this purpose, the following fruit types were used: pineapple, bananas, apricots, coconut, peach, goji, kiwi, mango, rosehips, cranberries and papaya. The fruits were previously dried in a home-scale dehydrator for 20 h at 60°C. After one month from addition of dried fruit, the function-enhanced vinegar samples were analyzed in terms of total phenolics content and antioxidant activity. Our results show that the manufacture of apple vinegar in home conditions represents an easy way to exploit the apples with inadequate quality to be used as fresh fruit or to valorize the by-products resulted from manufacture of canned apple products. Also, the incorporation of dried fruit has added value to apple vinegar by enhancing its antioxidant function and improving the sensory properties.

Keywords: apple vinegar, dried fruit, function-enhanced apple vinegar, total phenolics, FRAP values

1. Introduction

Vinegar can be obtained following different methods and using various raw materials. As substrates in the vinegar technology can be used white and red wine, apple cider, musts obtained from various fruits, malted barley or pure alcohol [1, 2]. The industrial production of vinegar was improved with the development of many technical devices. These improvements resulted in the increasing of the speed of fermentation by which the ethanol is transformed into acetic acid in the presence of acetic acid bacteria [3]. Apple vinegar is one of the most popular vinegar widely used for their medicinal and culinary benefits because it contains various healthful bioactive compounds derived from the fruit**.** Apple vinegar can be obtained by a two-step fermentation process, and at the end of the process the concentration of acetic acid is equal or above 4% [4]. The quality of apple vinegar as finished product is influenced by different factors among which the raw material and the technological process and equipments are of the great importance [5]. This product can be made from apples or parts of apples resulted as by-products in the industry of canned products. The raw material for apple cider vinegar is available in huge quantity taking into account both the quantities of apples produced every year as well as the peels and cores outcomes from the fruit canning industry. Many studies have reported that apple vinegar possesses functional properties, in particular antioxidant properties due to polyphenols and vitamins, health effects such as anti-diabetic due to

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the beneficial action on blood sugar levels, antimicrobial properties, antitumor, anti-obesity and antihypertensive effects [6, 7]. Also, apple vinegar consumption improve the ability of body to absorb the essential minerals locked in foods, might improve the cognitive function in humans and led to significant reductions in harmful blood lipids [8-10].

Recent studies have shown that the antioxidant compounds of apple vinegar include catechin, epicatechin, gallic, caffeic, p-coumaric, ferulic and chlorogenic acids [11, 12]. The wide variety of vinegars available today is nothing surprising. Apple vinegar has a milder taste than distilled vinegar being preferred for manufacturing of flavored vinegar. The flavoring can be realized by addition of fruit, herbs and spices. The addition of dried fruit in vinegar represents an easy and fairly safe way to obtain various types of vinegar with improved sensory and functional properties due to a high level extraction of bioactive compounds.

Drying represents an ancient method used to preserve and prolong the shelf life of food products. The content of bioactive components greatly varies with drying temperature and sharply decreased when the temperature is over 80°C. Although important losses seem to occur by dehydration, the dried fruit represent a source of bioactive compounds. To preserve the nutritional and sensory quality of fruit, choosing the best technique and drying conditions is essential [13, 14].

The main objective of this study is to manufacture the apple vinegar by a traditional procedure suitable for small-scale systems or for households. Our ultimate intention is to use various fruit and mixture of fruit, dried in mild conditions, as ingredients rich in bioactive compounds to fortify the antioxidant function of apple vinegar.

2. Material and methods

Manufacture of apple vinegar (AV)

For AV obtaining it was used the slow fermentation process known as Orleans method [2]. Thus, the apples were washed with water and the damaged parts were taken away. Then, they were cut in small pieces and mixed with warm water (0.5 L water for each 0.4 kg fruit). Additionally, for each liter of water used in the vinegar recipe it was added sugar (100 g), yeast (120 g) and black bread (20 g) to accelerate the fermentation process. The mixture was kept in an open vessel with a high diameter/height ratio, exposed to air at a temperature of 25-30°C and periodically stirred. During the first phase of acetic fermentation that lasted 10 days, the mixture was homogenized two times a day. At the end of this phase, the mixture was filtered and the obtained juice was stored in a recipient exposed to air and sunlight. At this stage, sugar (100 g/L juice) was added. The second phase of fermentation lasted between 6-8 weeks, until the liquid became clear. At the end of fermentation process, AV was filtered and used to obtain function-enhanced samples. The titratable acidity of AV was evaluated by titrimetric method according the Association of Official Methods of Analytical Chemists [15] and expressed in % acetic acid.

Fruit drying and preparation of function-enhanced AV samples

The fruits used in this study such as pineapple (1), bananas (2), apricots (3), coconut (4), peach (5), goji (6), kiwi (7), mango (8), rosehips (9), cranberries (10) and papaya (11) were purchased from local supermarket (Timis county). Prior addition in AV, they were thinly sliced and subjected to drying in a Heinner (Germany) dehydrator. Goji, rosehips and cranberries were dried as whole fruit. After drying at 60°C for 20 h, the fruits were cooled over night at room temperature and further, each of them was added to 500 mL AV in a proportion of 5% (w/v). Also, seven mixtures (M1-7) of dried fruit were prepared as follows: M1 (coconut: 15.00 g/L, pineapple: 14.00 g/L, papaya: 21.00 g/L); M2 (cranberries: 20.00 g/L, rosehips: 30.00 g/L); M3 (goji: 27.50 g/L, peach: 22.50 g/L); M4 (goji: 32.50 g/L, apricots: 17.50 g/L); M5 (cranberries: 31.00 g/L; peach: 19.00 g/L); M6 (bananas: 12.50 g/L, kiwi: 22.50 g/L, mango: 15.00 g/L); M7 (cranberries: 29.00 g/L, papaya: 21.00 g/L). All bottles of flavored AV, prepared in triplicate, were closed and kept in dark, at room temperature for 1 month. The AV without any addition was used as control.

FRAP assay

The antioxidant activity of dried fruit as well as of function-enhanced AV samples was evaluated by ferric reducing antioxidant power (FRAP assay) [16]. Thus, the mixture consists of 2 g of dried fruit, respectively 2 mL AV and 20 mL ethyl alcohol 70% (v/v) was subjected to sonication for 60 min at room temperature, than filtered and the filtrate was further used for analysis. The FRAP values were expressed as mM Fe^{2+}/100 g d.s for dried fruit samples, or mM

Fe^{2+}/L for AV samples, respectively. All determinations were done in triplicate.

Total phenolics content (TP)

Total phenolic content was evaluated on the base of Folin-Ciocalteu colorimetric method [17] and the results were expressed as mM gallic acid equivalents (GAE)/100 g d.s for dried fruit, and mM GAE/L for AV samples. All determinations were done in triplicate.

3. Results and discussion

The apple vinegar was obtained through double fermentation process both alcoholic and acetic. The traditional Orleans method used in this study is one of the oldest techniques applied to manufacture vinegar. In the first step of fermentation, the yeasts ferment the apples sugars to alcohol and in the second phase, the acetic acid bacteria (*Acetobacter*) convert the obtained alcohol to acetic acid. The acetic oxidation was monitored by determination of the acetic acid formed in the process. The finished apple vinegar contains 4.9% acidity expressed in acetic acid. Traditional apple vinegar production by the surface method takes several months. Our study proves that the apple vinegar can be obtained with inexpensive costs as regards the raw material and the used equipments.

The fruit drying is of the great interest for food technologists due to the seasonal character of fruit and to the opportunity to use them as functional foods ingredients. Drying of agricultural products seems to be an extremely important issue, especially when the final purpose is to use the dried products as ingredients for developing of new nutraceutical products [18]. It is well-known that the temperature-dependent processes lead to significant changes at a molecular level. Drying of fresh fruit, in order to be further use in various food applications, lead to alterations of physico-chemical and biological properties that significantly affect the quality of the finished products [19, 20]. To preserve the essential bioactive compounds to a high extent depends on the drying conditions [21].

The depletion of bioactive constituents during fruit drying is particularly due to the duration and temperature, because these compounds are greatly sensitive to heat and oxygen [22]. A number of recent studies have shown that the acceptable losses in the content of bioactive compounds were recorded when the drying temperature not exceed a value of 60°C [13, 14, 18].

Thus, the fruit drying was carried out up to a moisture level at which both microbial spoilage and deterioration resulting from biochemical reactions is significantly decreased.

Considering the aforementioned data, the fruit drying was conducted at 60°C for 20 h to obtain minimum level of losses in health beneficial compounds but also taking into account the feasibility of the process. Table 1 shows the fruit moisture before and after drying in mild condition. It can be noticed a massive water loss by dehydration, the final moisture of fruit ranging from 3 to 6.5%.

Table 1. The moisture of fresh and dried fruit

Fruit	Moisture (%)	
	fresh	dried
Pineapple (1)	87.23	4.83
Bananas (2)	74.19	4.14
Apricots (3)	85.13	5.28
Coconut (4)	60.42	5.14
Peach (5)	86.93	6.43
Goji (6)	55.11	3.09
Kiwi (7)	82.73	4.22
Mango (8)	72.15	5.61
Rosehips (9)	56.79	3.17
Cranberries (10)	87.56	3.24
Papaya (11)	86.21	3.58

Table 2 reports the FRAP values and TP content of dried fruit used as ingredients for flavoring of apple vinegar.

Table 2. TP and FRAP values of dried fruit

Fruit	FRAP (mM Fe^{2+}/100 g d.s)	TP (mM GAE/100 g d.s)
Pineapple (1)	12.40±0.54	46.80±2.09
Bananas (2)	25.39±1.18	50.12±2.35
Apricots (3)	23.54±1.07	46.70±2.13
Coconut (4)	12.50±0.57	42.53±2.04
Peach (5)	20.30±0.89	45.23±2.26
Goji (6)	46.20±2.18	210.00±8.45
Kiwi (7)	13.34±0.62	81.25±3.28
Mango (8)	17.09±0.79	20.61±1.07
Rosehips (9)	29.84±1.17	102.00±4.31
Cranberries (10)	41.47±2.07	178.02±6.53
Papaya (11)	10.60±0.63	42.48±2.17

The aforementioned data suggest that the highest values of both TP and FRAP are revealed in goji, cranberries and rosehips. At an opposite side, the smallest value of TP was recorded in mango while pineapple, bananas, apricots, coconut and papaya showed values in the range 42-50 mM GAE/100 g d.s.

As regards the FRAP values, the smallest values were obtained for papaya, pineapple, coconut and kiwi. Middle values of antioxidant capacity were recorded for bananas, apricots and peach.

Figures 1 and 2 depict the TP values of AV with addition of dried fruit or mixture of dried fruit.

Data shown in Figure 1 indicate that the highest values of TP were recorded as follow: AV+6>AV+10>AV+9>AV+7. Accordingly, the highest TP values of vinegar samples with mixtures of dried fruit were recorded as follows: AV+M4>AV+M2>AV+M5>AV+M7. These results are strongly correlated with the TP content shown in Table 2.

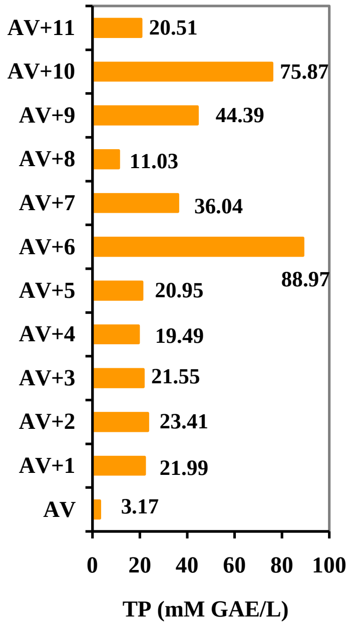

Figure 1. TP of AV with addition of dried fruit

In Figures 3 and 4 are shown the FRAP values of AV samples with addition of dried fruit as well as with addition of different mixtures of dried fruit. It can be noticed that the FRAP values of AV are enhanced according to the antioxidant potential of the original dried fruit. The antioxidant characteristics of AV samples with dried fruit addition were superior to the control sample prepared without any addition. The highest values of antioxidant capacity were recorded in AV samples with addition of goji, cranberry and rosehips as well as in vinegar samples obtained with mixtures containing these fruits.

Taking into account the values recorded for FRAP and TP for dried fruit used in the recipe of flavored vinegars, we can obtain the theoretical values of these parameters in the prepared AV samples.

In all cases the theoretical values are superior to the values resulted after analysis. The difference between theoretical and practical values is due to the extraction yield of antioxidant compounds in AV. The extraction yield of bioactive compounds was within the range 84-87%.

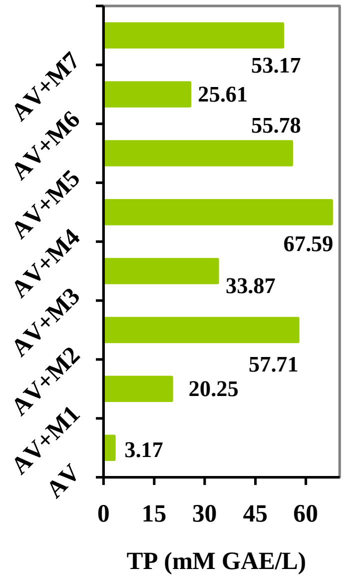

Figure 2. TP of AV supplemented with mixtures of dried fruit

Thus, these findings prove that AV is a proper media for extraction of antioxidant compounds of dried fruit. Also, the high availability of these compounds in AV entitles us to say that the followed technological way could allow designing of new products with enhanced antioxidant function.

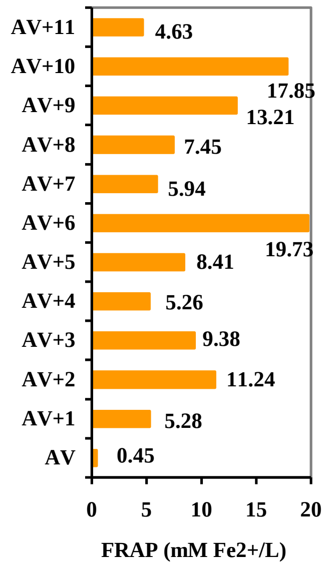

Figure 3. FRAP values of AV with addition of dried fruit

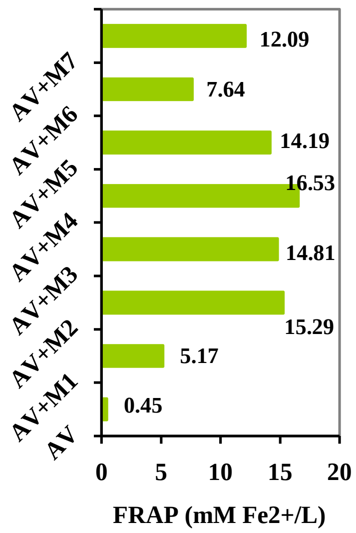

Figure 4. FRAP values of AV supplemented with mixtures of dried fruit

4. Conclusions

The results of this study prove that it is possible to develop new types of flavored AV by incorporation of dried fruit to take advantage of nutritional benefits that originate from the bioactive compounds in the fruit. Although fruit drying leads to inherent losses, the operation under mild temperature conditions has the potential to preserve the native bioactive compounds. The supplementation of AV with dried fruit or them mixtures resulted in obtaining of some products with enhanced antioxidant function. The antioxidant features of the obtained products are influenced by the fruit type incorporated into vinegar and also by the dried fruit mixtures composition. Practical application of this research comes from the fact that our data could be useful for producers to design various types of vinegar with fortified antioxidant function by incorporation of dried fruit to a mild temperature.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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