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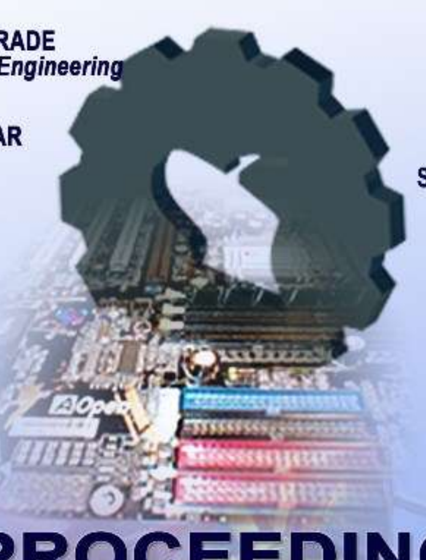

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TECHNICAL REVIEW ON PROPERTIES, UTILIZATION AND DRYING OF APPLE POMACE

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Abstract: *Apple pomace is one of the byproducts of the juice industry and represents a huge waste of biomass. According to many authors, the apple pomace comprises round 25% of overall mass of the fresh apples used in juice industry. Not only it represents a huge waste of useful material, but there is also an emerging problem of its disposal. In order to perceive all the benefits and possibilities of the apple pomace utilization, a review was needed to be written. This article describes the properties of the apple pomace and its potential uses. Furthermore, the drying process of apple pomace was reviewed as one of the best ways for preserving food and organic materials. The different drying methods and parameters of the apple pomace were reviewed.*

Key words: *Apple pomace(AP), AP Properties, AP Applications, Drying*

1. INTRODUCTION

The annual worldwide apple production for 2016 was round 84.6 million tons (UN Food & Agriculture Organization 2017). Of this amount round 13% is converted to apple juice concentrate (Shalini & Gupta 2010). In apple juice production, round 75% of the apples is converted to juice, while the rest, round 25% is the waste product comprised of apple skin, seeds and stem, known in the literature as apple pomace (Yates et al. 2017), (Dhillon et al. 2013), (Shalini & Gupta 2010). This huge quantity of juice produced has for a consequence significant amount of waste. In particular, the production of apple juice generates up to 12 million tons (Mt) of waste. The types of by-products from apple processing is given in figure 1 (Rabetafika et al. 2014). The disposal of this type of waste presents a big challenge and economical issue. One of the best ways to solve this problem is certainly the reuse of such materials. According to the number of researches (Shalini & Gupta 2010),(Reis et al. 2012),(Figuerola et al. 2005), apple pomace contains significant amount of nutritive value substances, such as pectin, antioxidants and vitamins. By recovering a part of the nutrients, it is not only possible to make use of the recycled food, but also tackle another important problem, i.e. disposal of the apple pomace. According to (Shalini & Gupta 2010) apple pomace disposal represents a big environmental problem, because the process of fermentation requires 250-300g/kg amounts of chemical oxygen. Furthermore, there is an emission of green house gases related with its disposal (Yates et al. 2017), which are known for its detrimental effect on the atmosphere. Fresh apple pomace contains significant amount of water, what makes it susceptible to spoilage, and thus makes the process of storing for longer time difficult (Shalini & Gupta 2010). One of the best ways for preserving the apple pomace from a spoilage is by drying it, what in addition helps preserving valuable nutritive substances, if dried properly (Shalini & Gupta 2010). Also, apple pomace drying is one of the most economically feasible ways, because it drastically reduces the volume and consequently lower transportation costs (Sato et al. 2010). In this work, the characteristics and nutritive values, as well as utilization and drying methods of apple pomace will be reviewed.

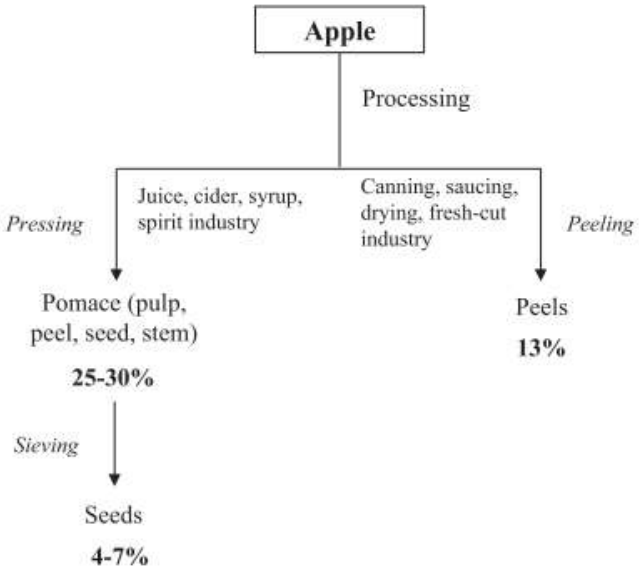

Fig. 1 By-products from apple processing

2. PROPERTIES AND NUTRITIVE VALUE OF APPLE POMACE

Apple pomace (AP) is the main by-product of apple juice industry and consist mainly of carbohydrates, dietary fibre and small amounts of protein, fat and ash. In addition, AP is also a good source of phytochemicals such as phenolic acids and flavonoids, which makes AP a valuable source of antioxidants (Rana et al. 2015), (Reis et al. 2012). Concerning the antioxidant properties of AP, it is both beneficial for the human health and would play an important role in diseases prevention (Sato et al. 2010), (Reis et al. 2012), (Sudha et al. 2007), (Schieber et al. 2003), (Rana et al. 2015).

Regarding moisture content, AP typically has 66.4–80% moisture on wet basis and contains between 23.7-26.4% of dry matter. Glucose, fructose, and sucrose comprise 14% of its total soluble solids. AP is composed of pulp and epidermis (95.5%), seeds (4.1%), and stems (1.1%). The dietary fiber content ranges from 11.6 to 44.5% with 35.8% on average (Schieber et al. 2003). Pectin in AP is present with 3.5% - 18%, i.e 10-15% on average. In addition, AP contains 4.0% proteins, 3.6% sugars, 6.8% cellulose, 0.38% ash, 0.42% acid and calcium and 9.5–22.0% carbohydrates.

AP including seeds has been proven to be a rich source of polyphenolics, and some phenolic constituents, such as the procyanidins and quercetin glycosides, have been shown to have strong antioxidant activity. Dietary fibers are proven to have very important role in improvement and preservation of human health, especially regarding gastrointestinal system. (Rana et al. 2015). Type and source of dietary fiber greatly influence their functional properties. Presently, the primary sources utilized in food industries are of cereal origin with minimal contribution from fruits and vegetables. However, AP has additional benefits because of the presence of number of bioactive components, especially antioxidant molecules, for which it has enormous potential as dietary food component.

The major part (approx. 95%) of the AP are skin/pulp tissues, which consists of cell wall polysaccharides (e.g. pectin, cellulose, hemicellulose, lignin and gums) and skin bound phenolic compounds, such as dihydrochalcones, flavonols, flavanols and phenolic acids (Rana et al. 2015).

3. Utilization of the apple pomace

The AP has traditionally been used as cattle feed. The reason is that the AP in its wet form is susceptible to spoilage, and therefore, the range of fresh AP utilization purposes is generally reduced (Shalini & Gupta 2010). Common applications of this by-product are the direct disposal to soil in a landfill and for pectin recovery (gelling agent, stabilizer and source of dietary fiber). (Reis et al. 2012). AP contains many valuable compounds that proved to be useful in human diet, such as carbohydrate, pectin, crude fiber and minerals. However, the main reasons why the AP is at this stage not exploited enough are economical.

In the review of (Yates et al. 2017) the AP has been used till now for number of purposes: production of biofuels, substrate for enzymatic processes, extracted for antioxidants, as a source of bioenergy, or sorbents for effluent cleaning. (Figuerola et al. 2005) and (Sudha et al. 2007) discussed the AP as a source of the fibres and polyphenols. Another use of AP is making alcoholic apple spirits as discussed in (Rodríguez Madrera et al. 2013). AP was also studied in (Ahmad et al. 2017) for the formulation of gluten free crackers. According to (Rabetafika et al. 2014) the production of fibre concentrate and pectin from AP is currently the most economically justified process and has potential to be commercialized. In (Bhushan et al. 2008) review is discussed about AP processing for bioactive molecules such as dietary fibre and pectin, xyloglucan, etc. The author suggested that in last period there is a growing trend of utilization AP for extracting valuable nutritive substances. In the next paragraphs we will review the most common uses of AP with a special focus on bioactive components extraction.

Food products. In the review of (Shalini & Gupta 2010) few authors have reported the making of food products from AP in the past including AP jam, sauce and papad and citric acid. In the same review is also mentioned that Rotova GP developed a technology for preparation of apple powder, Wang and Thomas used drum dried AP in bakery products, Shah and Masoodi prepared beverages from apple pulp that were satisfactory, while Kaushal and Joshi prepared cookies by incorporating different amounts (10–50%) of apple pomace powder in dough. (Rodríguez Madrera et al. 2013) made AP spirits were from dry pomace and selected yeasts strains. Recently, the AP flour was developed in Austria (Obstpresse Bramberg, Kulturverein Tauriska & Olschnögger n.d.). The AP is squeezed, grinded and packed, and is excellent to use for bakery products. (Sudha et al. 2007) prepared the blend of finely grounded AP and incorporated it in wheat flour with 5%, 10% and 15% and studied the mixture for rheological characteristics. Finally, they prepared a cake of wheat flour with 0–30% AP incorporated in it. AP was also studied in (Ahmad et al. 2017) for the formulation of gluten free crackers. The authors studied the formulation of gluten free crackers based on the two varieties of brown rice flour and AP. The percentage of AP in the flour were 0%, 3%, 6% and 9%.

Pectin extraction. The extraction of pectin from AP is a well-known process discussed a lot in last few decades (Shalini & Gupta 2010). Pectin is used in food as a gelling agent, thickener, texturizer, emulsifier and stabilizer. The production of pectin is considered the most reasonable way of AP utilization both from an economical and ecological point of view, and as well one of the most practical approaches (Sato et al. 2010), (Bhushan et al. 2008)

In the work (Sato et al. 2010), the eleven selected apple cultivars were mixed and treated in order to explore the characteristic of every composition. The principal component analysis established the efficiency of total phenol compound, antioxidative capacity, total fiber and total reducing sugars to identify the best cultivar set as source of bioactive compound. Samples of selected apple cultivars were 10 kg each. The method included juice extraction in a vertical press. Then, the AP was rinsed once with tap water (1:1:w:v) and centrifuged at 860 x g in a small scale domestic equipment until total drainage. The rinsed AP was then spread as a thin layer in circular bamboo support in each of the six trays of a laboratory oven, and was left to dry under circulating air at 60ºC. The extraction of pectin in this paper was made in accordance with the procedures previously described by Fertonani et al. (2006). A mixture of raw material (10 g) with 400 ml aqueous HCl (100 mM) was boiled during 10 min and the reaction was stopped in an ice bath; the slurry was filtered through cheese cloth and the pectin was precipitated from the clear extract using alcohol (1:2::v:v). After filtration through cheese cloth and drying in an oven with circulating dry heated air at 50 ºC, pectin was triturated in a Waring blender and stored at 22ºC±3ºC in plastic bags containing silica gel for further analysis. The average total polyphenol content detected in this study was 4620 mg kg-1 and the average antioxidant activity was 36.69 mMol g-1. One of the conclusions of this paper is that the polyphenolic compounds in the AP have a high correlation with the antioxidant activity.

In (Schieber et al. 2003) the process for combined recovery of pectin and phenolic compounds from AP is described. The process includes extraction of dried AP with diluted mineral acid and adsorption of phenolic constituents by a hydrophobic styrene–divinylbenzene copolymerisate. Acidic pomace extracts and dried apple seeds were held frozen at -20 ^{o}C until use. The acidic pomace extract was preheated at 60 ^{o}C in a water bath and then applied to the column at a flow rate of approximately 10 bed volumes per hour. The pectin-containing effluent was collected, and residues of pectin were removed from the column with distilled water until no pectin could be detected by alcohol precipitation. The authors concluded that the apple seeds are a promising source of valuable compounds which may be used as healthy food.

In (Constenla et al. 2002) the pectin was extracted from dried apple pomace in a nitric acid solution (pH=2.5) for 1 h with solid:liquid ratio of 0.04 kg:L,at 80 ^{o}C. After extraction, the pectin solution was filtered through a Buchner funnel with a filter paper and diatomaceous earth pre-coat, and concentrated under vacuum (60^{o}C) in a Buchi Rotova-porator, volume ratio 4:1. Concentrated pectin solution was precipitated with ethanol (0.96mL/mL) and the resulting product washed twice with 0.70mL/mL and 0.96mL/mL ethanol, respectively. Pectin precipitate was then filtered through filter paper and dried under vacuum at 45^{o}C to constant weight. Dry pectin was ground to pass a 100-mesh sieve.

Source of fiber. Dietary fibre comprise of soluble and insoluble part constituted mainly by carbohydrate polymers with ten or more monomeric units that are non-hydrolysable by the endogenous enzyme in small intestine of human. It includes associated compounds like lignin in the case of plant origins. According to (Rabetafika et al. 2014), many studies report the feasibility of dietary fibre extraction at large scale.

In (Ahmad et al. 2017) soluble, insoluble and total dietary fibre content of the samples was measured according to the method described by Asp et al. (1983). Sample (1.0 g) was homogenized in 20 ml of sodium phosphate buffer (0.1 M, pH 6.0) and was treated with heat stable a-amylase (Termamyl) (90 ^{o}C, 15 min) and then digested with pepsin (40 ^{o}C, 60 min) and incubated with pancreatin (40 ^{o}C, 60 min). Soluble and insoluble dietary fibres were separated by filtration. The filtrate was subjected to ethanol precipitation and filtered to obtain soluble dietary fibre and both the precipitates were dried overnight at 105 ^{o}C and were incinerated at 500 ^{o}C for 6 h. Total dietary fibre was then calculated as combined value of soluble and insoluble dietary fibre.

(Figuerola et al. 2005) evaluated the functional properties of fibre concentrates from apple and citrus fruit residues, in order to use them as potential fibre sources in the enrichment of foods, was carried out. Residues from juice extraction of grapefruit (Ruby and Marsh cultivars), lemon (Eureka and Fino 49 cultivars), orange (Valencia cultivar) and apple Royal Gala (Granny Smith and Liberty cultivars) were used as fibre source. Apple fibres were obtained by washing, coring, chopping, and separation of juice from pomace by pressing. AP was washed twice with warm water (30 °C); then it was dried at 60 °C during 30 min in an air tunnel drier and ground to a particle size of 500–600 lm. Fiber concentrates were analyzed for their proximate content (moisture, lipids, protein and ash); caloric value; dietary fibre composition and functional properties (water retention capacity – WRC, swelling capacity – SW, fat adsorption capacity – FAC and texture). The conclusion was that all the fibre concentrates had a high content of dietary fibre (between 44.2 and 89.2 g/100 g DM), with a high proportion of IDF. Protein content ranged between 3.12 and 8.42 and lipids content ranged between 0.89 and 4.46 g/100 g DM. The caloric values of concentrates were low (50.8–175 kcal/100 g or 213–901 kJ/100 g). It was found out that the texture was strongly dependent on the particle size and it was increased by the heat treatment.

4. APPLE POMACE DRYING

Drying is one of the oldest and well-known methods of food preservation. Fresh fruit has a short shelf life because it has a high moisture and sugar content, allowing microorganisms to grow, which makes it susceptible to spoilage. Thus, drying helps extend the shelf life of fruits through reducing water activity (Aldosari 2014). Direct drying without pretreatment is the most common industrial operation and economical approach for obtaining valuable fractions from the AP. (Rabetafika et al. 2014). The goal of the drying is to remove moisture from AP in order to avoid growth of microorganisms and reduce the activity of enzymes, while saving valuable quality components, such as antioxidants and phenolic compounds.

In (Aldosari 2014) the AP was dried with three different methods: freeze drying, cabinet drying and drum drying. The goal of the experiments was to determine the effect of the three different drying methods, mentioned above, on color, antioxidants and phenolic compounds of the material. The samples were prepared differently for each type of drying. For drum drying samples of 1.6 kg of AP were mixed with water (1:2) to pour the slurry onto a drum dryer. For the hot air drying the perforated tray was loaded with approximately 150g for each temperature.

Drum drying. This drying method has favorable characteristics for commercial production, such as low cost, rapid drying time, and large throughput. Samples of 1.6 kg of AP were mixed with water (1:2) to pour the slurry onto a drum dryer. The experiment was conducted three times. Drum drying was run continuously for 15 minutes at a drum surface temperature of 140 °C. The temperature of the drum was estimated using an infra-red thermometer. The sample slurry was dried by pouring it on to the hot surface of the drums, then by using knives to continuously scrape off the sample from the drum so that the dried product was collected in stainless steel trays.

Hot-air Drying. The samples were dried at different air temperatures at 60 °C, 80 °C, or 100 °C. The drying time was 25, 20 and 15 minutes respectively. The relative humidity was 30.7%, 35.3% and 39% respectively. After drying, the content of moisture in AP was 3.0%, 3.0% and 3.2% respectively. The perforated tray was loaded with approximately 150g for each temperature. The velocity of air was 15.2 m/s measured with a hot-wire anemometer.

Freeze drying. The freeze drying of AP was accomplished with Virtis Genesis (25L Genesis SQ Super XL-70, 2010). The freeze dryer has a sample chamber, seven shelves, a vacuum pump and a refrigerated condenser chamber. The shelf temperature was lowered to −30 °C, and the sample was placed onto shelves with the chamber closed. The condenser was lowered to –60 ºC and the vacuum pump was turned on until it pulled a near complete vacuum, approximately 50 mTorr. Then, the shelf heater was turned on to warm up the samples to around 20 ºC. Samples were dried for 3 days under these conditions, until the dryer had a stable reading of around 10 mTorr pressure inside the freeze dryer. The samples were removed and kept frozen in dark colored polyethylene bags at −20 °C.

The results of this study demonstrated that freeze drying was the best method to process AP for value-added ingredient use. The next best method was cabinet drying at lower temperatures, and finally drum drying. Although drum drying showed the most detrimental effect on color, phenolics, and antioxidants, its significantly lower cost and faster speed of drying may offset the negative nutritional effects. Drum-dried AP could be used as a low-percentage ingredient or blended with premium-dried AP to meet both cost and nutritional requirements, for example.

In the study of (Shalini 2010) the AP was dried in order to obtain the drying characteristics of AP.

The goals of the study were:

1. To study the drying behavior of wet AP under thin layer drying conditions in relation to drying air temperature, air velocity and layer thickness.

2. To determine the equilibrium moisture content of AP.

3. To test mathematical models for predicting wet AP drying rates.

4. Sensory evaluation of the dried AP powder at different conditions of temperature and layer thickness.

5. To optimize the drying air temperature and layer thickness on the basis of sensory evaluation.

Experiments were planned to develop dried AP powder. The wet AP cake with different layer thickness (2, 4, 6 mm) in three replicates was exposed to different temperatures in the range from 50°C to 70°C with an increment of 10°C at constant air velocity of 1.5m/s and different air velocity in the range of 1.5 to 2.5m/s with an increment of 0.5m/s at a fixed temperature of 70°C and fixed layer thickness of 2mm. Experiments were also conducted to study the effect of drying on color. The selected drying models were attempted on experimental data to describe the phenomena of drying process. The drying behavior of AP was mathematically analyzed by testing the validity of selected models. The mean prediction error and maximum error corresponding to 90% of the data points were calculated for the best fit model. The effect of drying air temperature, drying air velocity and layer thickness on color was studied by colorimetric method. The sensory evaluation for overall acceptability of dried AP powder was also studied to optimize the drying conditions. On the basis of experimental results and data analysis, the author concluded the following:

1. Drying of AP takes place in falling rate period.

2. The overall drying rate linearly increased with increase in temperature and decreases with increase in layer thickness.

3. As the temperature increased, equilibrium moisture content of the AP decreased.

4. Page's model most closely predicted the drying behavior of AP with maximum error at 90% data points (E90) less than 12% and average mean error in the range of 0.084 to 0.305 % for the different individual set of conditions.

5. AP should be dried at 60 °C with 4 mm of layer thickness at 1.5 m/s or higher air velocity, as these drying conditions resulted in best quality of the product (dried AP powder) on the basis of overall acceptability of the product.

In the paper (Constenla et al. 2002) the effect of temperature used for drying apple pomace on apple pectin characteristics, including chemical composition, color and gelpoint temperature (Tg) was determined. The AP was obtained from commercial Granny Smith apples. Apple fruits were washed and crushed. Juice was extracted by pressing in a hydraulic rack-and-cloth press (180 kPa for 10 min) and pomace dried in the same continuous, rotary drier used by Pelegrina et al. (1998). Drying conditions were speed of rotation - 17 rpm; air velocity - 1.5 m/s; initial pomace load - 2.3 kg; and four values of air temperature (Tdr = 60°C,70°C,80°C and 105 °C) measured at the air outlet. Initial pomace moisture content was approximately 0.80 g/g. A typical experimental run lasted 6–8 h to reach a final to initial water content ratio (X/Xo)<0.07, where X is the water content, depending on the air temperature. The author concluded that the temperature during AP dehydration in a rotary drier affected both the degree of esterification and the degree of polymerization (molecular weight) of extracted pectin. The higher Tg value was obtained with pectin extracted from AP dried at 80 °C. Gel point was shown to be more sensitive to Tdr than other quality parameters: while DM had the same value both at 80 °C and 105 °C, minimum Tg occurred at the higher temperature. This behavior author attributed to the heat-induced reduction in Mw.

In (Ahmad et al. 2017) apples were cut into small pieces and crushed into the juicer mixer. The juice was squeezed completely from the pulp and pomace was dried in tray drier at 40°C and grounded with grinder mill and sieved into a fine powder.

In (Figuerola et al. 2005), AP was dried at 60 °C during 30 min in an air tunnel drier and ground to a particle size of 500–600 lm. Drying at temperatures below 65 °C avoids changes in the functional properties and in the content of poly- phenols, tannins, anthocyanidins and proteins.

For the study of (Rodríguez Madrera et al. 2013) the apple pomace came from industrial hydraulic presses with an operating capacity of 15,000 kg belonging to the same cellar in two consecutive harvests (2010 and 2011). Nine batches of 50 kg were taken during each harvest, each of which was dried in an oven with air circulation at 60◦C for 48 h. The different batches of dry pomace were homogenized and placed in 6.8 kg portions, keeping them in sealed bags to preserve them from moisture until the time of fermentation.

In (Schieber et al. 2003) wet apple pomace (25–30% dry matter) of industrial juice production was dried in a three-stage drum dryer within 5–8 min by hot air (300–700 °C). The temperature of the pomace did not exceed 50–60 °C during the drying process.

In the table 1, it was given a short review of the methods and few parameters of AP drying.

Table 1 Methods and parameters of AP drying

Drying method	Temperature [°C]	Drying time	Air velocity [m/s]	Reference
Drum dryer	140	15 min	-	(Aldosari 2014)
Hot air dryer	60	25 min	15.2	
	80	20 min		
	100	15 min		
Freeze dryer	-30	3 days	-	
Hot air drying	50	-	1.5	(Shalini 2010)
	60		2	
	70		2.5	
Rotary dryer	60	6-8h	1.5	(Constenla et al. 2002)
	70			
	80			
	105			
Tray dryer	40			(Ahmad et al. 2017)
Air tunnel dryer	60	30 min		(Figuerola et al. 2005)
Oven with air circulation	60	48h		(Rodríguez Madrera et al. 2013)
Drum dryer	300-700	5-8 min	-	(Schieber et al. 2003)

5. CONCLUSIONS

Apple juice industry produces large amount of by-products called apple pomace (AP). In the past it was almost exclusively treated as a waste and disposed. However, the efforts have been made to prove that the utilization of AP is feasible and convert it from cattle food or waste into raw material for extraction of valuable nutritive substances, such as phenolic compounds, fibres, antioxidants, pectin, etc. In this work, the properties and nutritive values of apple pomace were reviewed. Then, the utilization of apple pomace for food production, pectin and fibre extraction was reviewed. At the end, the drying methods and parameters were summarized. The AP has a potential for becoming so called re-used or up-cycled food in the human food chain.

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