

# Innovation and Practice of Separation Pre-Pressing Technology and Whole Apple Utilization

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## Abstract

Apple and apple products are one kind of popular fruit and fruit products among the world. The planting acreage, output and trade quantity of the apples in the world are keeping increasing. At present, China has become the biggest apple producing and trading country. However, Chinese companies of concentrated apple juice suffer a serious deficit since the global financial crisis. The most important reasons are the rising cost of raw materials, less utilization and the single products. In order to solve these problems, pressing pre-peeled apple and the whole apple utilization were proposed, which not only solved the less processing quality, discoloration, pesticide residues and other issues, but also processed apples based on the nutrients of different parts (juice, flesh, peel and seeds). It may extend juice processing chain and achieve zero waste of processing apples which will be the future direction of the juice industry.

## Highlights

- Separation pre-pressing technology and the whole apple utilization were proposed to solve apple processing problems.
- The characteristics of every part of apple made by separation pre-pressing technology were reviewed.
- This technology can be a good example of the management of by-products generated by fruit-vegetable industry.

**Keywords:** Separation pre-pressing; Whole fruit; Utilization; Zero waste

## Introduction

Apple and apple products, being rich in functional compounds, are highly consumed all over the world. China exports 600,000 tons of concentrated apple juice, ranking the first in the world [1]. Numerous fruit processing factories have been generating millions of tons of agro-industrial wastes such as apple peel, apple flesh, apple seeds, which has become a severe environmental issue. They are usually treated as industrial wastes and often used as animal feed or composting resources. Disposal of such wastes also increases the operation cost of manufactures. Although apple pomace has potential to be transformed into various food ingredients e.g. alcohols pectin, enzymes [2-4]. These benefits seem to be unattractive for commercialization because of low utilization rate and substantial cost. Moreover, agro-industrial by-products represent not only an environmental pollution but also a waste of bioactive substance, which could be processed to kinds of high level products. According to epidemiologic studies, diets rich in fruits and vegetables play an important role in reducing the risk of developing chronic diseases, such as cardiovascular disease, cancer, diabetes, etc. [5-7]. Nowadays ingredients from natural raw materials are becoming increasingly popular among consumers. It is well known that apples contain a wide variety of phytochemicals, many of which have high antioxidant and anticancer activities [8]. Apple pomace also possesses a high amount of phytochemical compounds. Therefore, improving the utilization of raw material can not only reduce raw material waste, but also increase the profit.

However, it is difficult to achieve maximum utilization of agricultural by products by using some traditional methods (such as burning firewood, stack retting, direct feeding of livestock and poultry, etc.). Therefore, to improve the utilization of raw materials and accelerate the transformation and upgrading of enterprises, it's necessary to do

the research on whole fruit utilization techniques. Taking this into consideration, in this paper, research work on innovation and practice of pressing pre-peeled apple was carried out, the concept of whole apple utilization was proposed, and apple processed into various products like apple flesh powder and apple cuticular wax were also reviewed.

## Separation pre-pressing technology and its working principle

Technology of separation pre-pressing is one possible solution for apple pomace. At room temperature, after selection and cleaning, apples are conveyed to the pre-peeled equipment, which are not preheated. In the integral turbine cold extraction equipment, peel, peduncle and seeds are directly separated. Then, apple pulp are heated at low temperatures and put into spiral-filter press or belt press for subsequent processing. In this step, apple pulp is separated from apple peels, which may affect the quality of apple juice [9]. Technology of separation pre-pressing can decrease the activity of polyphenol oxidase, peroxidase, and pectin methylesterase, and thus reduces the enzymatic browning in apple juice.

Due to the relevant low temperature in the subsequent processing, it affects activity of other pectin decomposition enzymes which could facilitate the decomposition of pectin in the juice thus keeping color and stability of the products. Alvarez et al. [10] found that pectin molecules caused pectin-protein flocculation during the juice storage, requiring the removal of suspended material to prevent turbidity developed after bottling the juice. A stable cloud in most fruit juices and fruit-based beverages is perceived as an indicator of good quality [11]. The separation technology is based on the relevant mechanical equipment. A new type of juice extraction equipment (Figure 1), called separation pre-pressing machine, is made by the ministry of agriculture of

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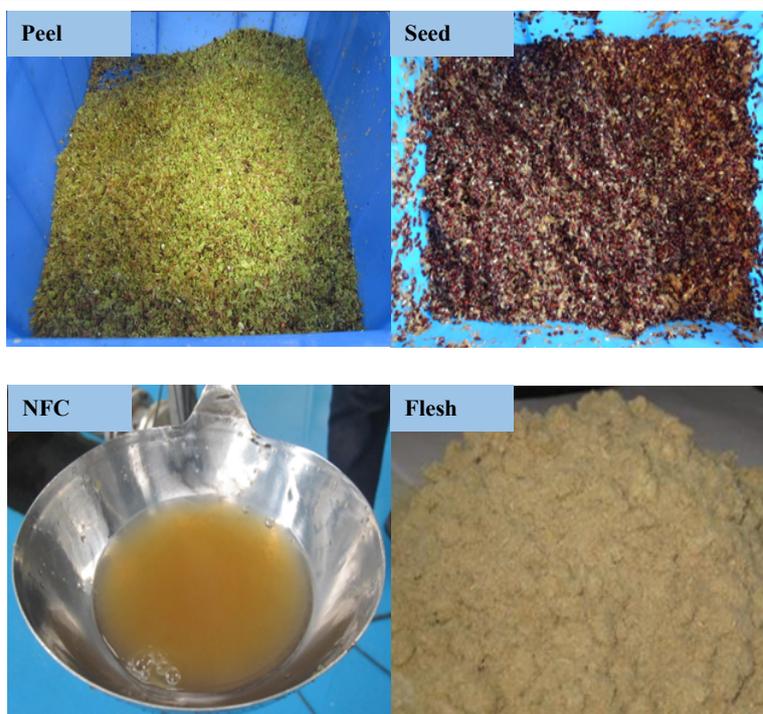
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**Figure 1:** Separation pre-pressing equipment made by the ministry of agriculture of modern apple industry technology system (depending on the Shaanxi Normal University) and Xi'an Ding He machinery manufacturing.



**Figure 2:** There is apple peel, apple seed apple juice and apple flesh obtained by the separation pre- pressing technology.

modern apple industry technology system (depending on the Shaanxi Normal University) and Xi'an Ding He machinery manufacturing. It works as follows, apples are fed to a hopper with a motor-driven screw and transferred to a stator which enables the uniform distribution of the apples inside the downstream paddle rotor, mounted inside a cylindrical screen, which removes the seeds, peels, and fulfills the pulp and juice extraction, finally achieving an effective separation of pulp from those undesired components, while no need of a crusher [12]. Apple pulp, apple peels and apple seeds can be obtained using the equipment in the Figure 2. Apples are broken and refined at the same time. Apple juice, apple peels, apple seeds and apple flesh are separated completely, which could eliminate undesired influence of apple pomace during the processing of apple juice. Overall, the separation equipment can improve the quality of juice and efficiently separate apple peels,

apple seed and apple flesh, which may make contribution to utilization of whole apple to make the value-added apple products. The separation technology greatly simplifies the utilization of solid materials generated in apple juice processing, establishing an innovative system to achieve whole fruit utilization.

### Whole apple utilization

In recent years, nutrient components in apple pomace have received increasing research attention. Proximate composition of apple pomace was listed in Table 1 [13-16]. Detailed composition of phenolic compounds in the peels, seeds and flesh recovered from apple pomace has been studied [17]. Proximate composition of different part of apple was shown in Table 2 [18]. As a rich source of carbohydrate, pectin, crude fiber and minerals, pomace has been utilized in various

Biomass components	Composition (dry-weight basis)	Micronutrients	Composition (dry weight basis) mg/kg
pH	3.81	phosphorus	0.10%
Ash	1.04 ± 0.01 (%)	Cu	11.8 mg/kg
Protein	1.9 ± 0.2 (%)	Fe	158 mg/kg
Total solids	27.53 ± 0.1 (%)	Zn	15.4 mg/kg
Soluble solids	2.23 ± 0.03 (%)	Mn	14 mg/kg
Insoluble solids	25.30 ± 0.03 (%)	Se	0.08 mg/kg
Water activity (aw)	0.84 ± 0.00 (%)	Mg	0.07%
Total dietary fiber	32.54 ± 0.5 (%)	K	0.75%
Vitamin B1	0.9 mg/kg	Na	0.02%
Vitamin B2	3.8 mg/ kg	-	-

Table 1: Compositional analysis of apple pomace.

Polyphenols	Phenolic content		
	Apple seed (mg/100gDW)	Apple flesh (mg/kg FW)	Apple peel (mg/kg FW)
Phloridzin	413.45 ± 4.54	9.2 ± 1.8	41.7 ± 4.8
Chlorogenic acid	21.43 ± 1.57	31.3 ± 0.5	24.2 ± 0.7
Procyanidin B2	2.89 ± 0.05	20.8 ± 1.6	156.5 ± 11.6
Catechin	2.48 ± 0.09	16.0 ± 2.7	89.9 ± 7.4
Caffeic acid	1.09 ± 0.01	0.3 ± 0.1	0.5 ± 0.1
Protocatechuic acid	3.29 ± 0.06	-	-
Quercetin	3.46 ± 0.18	-	-
Hyperin	54.72 ± 2.58	-	-
(-) Epicatechin	6.31 ± 0.23	22.0 ± 1.9	217.0 ± 9.6
Ferulic acid	-	0.2 ± 0.1	0.3 ± 0.1
Gallic acid	-	0.9 ± 0.0	2.6 ± 0.1
FRAP(μM TE/g FW)	161.70 ± 8.76	36.55 ± 3.76	75.94 ± 5.56
DPPH(μM TE/g FW)	52.23 ± 5.44	16.16 ± 1.02	17.87 ± 1.78
ABTS(μM TE/g FW)	298.24 ± 10.32	128.64 ± 7.45	245.17 ± 10.32

Table 2: Compositional analysis and antioxidant of different parts of apple (%).

forms in the past, but the problem of its utilization still exists. The large quantity of apple pomace suggests that the production of alternative products should be explored. With high antioxidant activities, every part of apple is a promising source of antioxidants and functional food ingredients. To achieve the zero-emission of apple pomace, reduce environmental pollution and promote economic development, the concept of the whole apple utilization was proposed. Separating apple before pressing, using separation pre-pressing technology and relevant equipment, which can be called technology of separation pre-pressing to improve the whole apple utilization and improve the apple juice ratio. The technology of separation pre-pressing greatly simplifies the process of utilization of fruit residues. At the same time, apple peel and apple flesh can be prepared for value-added products. For example, apple seed can be used for apple seed oil and apple seed protein extraction. Apple flesh can be prepared for food additives and dietary fiber powder. All these are based on diversified technologies to develop innovative new system. Making full use of apple will bring commercial benefits, and also reduce the cost (e.g. pomace waste treatment).

## Characteristics and Innovation of Apple Juice Made by Separation Pre-Pressing Technology

### The characteristics of the traditional apple juice

In the traditional process of concentrated apple juice, the fruits are washed on pools with the aid of pressurized water sprays to remove residues of soil and foreign matter before pressing [19]. After washing, apples are transported to the vertical, horizontal or belt presses. In the pressing stage, suitable quantity of ascorbic acid is added to apple juice as an anti-browning agent and solids including peel, flesh, seeds are

removed. After pressing, the juice is pasteurized, allowing a complete sterilization of microorganisms and inactivation of some enzymes such as phenol oxidase, which can effectively inhibit enzymatic browning of fruit juice. Enzymes like pectin enzyme and amylase are added into pasteurized apple juice to hydrolyze pectin substances, which are responsible for cloudiness, to prevent post-turbidity in fruit juice. Adsorption is the most important step to improve the color of apple juice, which can remove suspended materials resulting from enzyme activity [20]. For the beverage stabilization, treatment of gelatin, active carbon bentonite, Polyvinyl pyrrolidone (PVPP), silica gel and so on are widely used. Adsorbent and the adsorbed material can be removed by ultrafiltration. Apple juice is finalized by filling. In some plants the refined juice is concentrated and filling, whereas in others, refined juice may be directly destined to the formulation of juice or nectar, followed by pasteurization and filling.

However, many problems still exist in traditional apple juice processing, such as nutrition and aromatic substance loss, browning, post-turbidity and microbial problems during storage. Browning and post-turbidity, leading to some quality problems by giving the final product an unfavorable appearance or even result in food safety problem, are the main problems during the processing and storage. In order to avoid browning, relative higher temperature will be used to inactivate peroxidase, but it will cause the loss of flavor substances and nutrients, as well as reducing the quality of fruit juice. Post-turbidity is closely related to pectin, polyphenols and proteins, etc. In the traditional apple juice processing, ultrafiltration is used to avoid post-turbidity, but phenolic nutrients of the apple juice are removed together, reducing the nutritional value of juice.

## The characteristics of the apple juice made by separation pre-pressing technology

Browning and post-turbidity, two critical technical problems in the traditional process of apple juice, can be solved successfully by separation pre-pressing technology. In the apple juice made by separation pre-pressing, pesticides trichlorfon and dichlorvos can be reduced by 61.7% and 87.0%, respectively, in comparison with those made by conventional processing, which significantly improved the security of the juice. Amount of pectin and phenolics decreased 34.8% and 3.4%, respectively, Peroxidase and pectinase activities decreased 82.3% and 27.6%, respectively. There is no significant change of metal elements. Color value increased by 97.4% and organic acid content decreased by 10.6%. The stability study found that using separation pre-pressing processing can greatly improve the stability of the juice during storage [21]. The aroma components were also analyzed [22]. The results showed that 30 peaks were separated and 23 components were identified from juice made by separation pre-pressing. The content of aroma was 22.23 µg/mL which reduced by 59.11% compared to juice made in traditional way. The contents of alkene, esters, aldehydes, alcohol, ketone and acids aroma components decreased by 24.39%, 60.19%, 68.16%, 75.16%, 87.18% and 97.04%, respectively. The data showed that the effects of separation pre-pressing processing on aroma were significant. Generally, separation pre-pressing technology, to a certain extent, improves the quality of juice.

Separation pre-pressing is the new technology to process the apple juice at room temperature, not preheated and suitable for the production of Not From Concentrate (NFC) apple juice and smoothie. There is a lot of juice recovered from concentrated fruit juice on the market, seriously losing nutrients and flavor, but it is easy to store and at low prices that consumers can generally accept. In contrast, NFC is juice directly pasteurized after processing at low temperature. Because of the short heating time in process, there are less nutrition loss and better fruit flavor in comparison with traditional apple juice. It is suitable for low temperature preservation and has relatively short shelf life with high cost. Another type of product, smoothie, is a kind of fruit products. It is made by smoothie maker which mixes and breaks the fruit and ice at a high speed. Smoothie tastes fresh and pure with delicate texture. With the growth in consumer income, they preferred convenient and good quality products leading to great growth in NFC and smoothie.

## The Characteristics and Utilization of Apple Pomace Made By Separation Pre-Pressing Technology

Previous studies on apple products only took into account the apple pomace as a whole plant material without separating and investigating the different parts of apple fruit [17]. The new technology can make the apple pomace completely separate from apple juice to make best use of apple pomace. It provides a way to make use of every part of apple deeply.

## The characteristics and utilization of apple flesh made by separation pre-pressing technology

Apple flesh which is the most in the apple pomace has high content of fiber. Dietary fiber plays a positive role in healthy diet and its positive relationship with human health has been confirmed by the scientific community. Consumers are more and more care about nutrition and disease prevention, which is driving consumers buying natural, value-added foods or functional foods with higher levels of dietary fiber. The main characteristics of the commercialized fiber product are: total

dietary fiber content above 50%, moisture lower than 9%, low content of lipids, a low caloric value and neutral flavor [23]. Fruit fibers have better quality in water and oil holding capacities, soluble fiber contents, and colonic ferment ability than fibers from cereals which are common used [24]. Apple flesh also is a good source of dietary fiber for its high content antioxidant substances [25]. Sudha et al. [26] investigated apple pomace as a source of dietary fiber, polyphenols and its effect on cake making. Water absorption increased significantly from 60.1% to 70.6% with increase in pomace from 0% to 15%. Dough stability decreased and mixing tolerance index increased, indicating weakening of the dough. The total phenol content in wheat flour and apple pomace was 1.19 and 7.16 mg/g respectively whereas cakes prepared from 0% and 25% apple pomace blends had 2.07 and 3.15 mg/g indicating that apple pomace can serve as a good source of both polyphenols and dietary fiber. Owing to its high water content, apple flesh is susceptible to microbial degradation and it has to be dried to be stable for industrial exploitation. The viscosity of apple flesh is so high that it is very difficult to dry. Lavelli and Corti [27] investigated the effect of drying on apple phytochemicals and their degree of degradation during long-term storage as a function of  $a_w$ . They found that air-drying at 60°C was better than vacuum-drying at 40°C in terms of anthocyanin and flavanol retention. Yurong Guo used vacuum paddle drying method to dry apple flesh (Figure 3). Apple flesh can be made into apple flesh powder with good quality. Dried apple flesh powder can be added to food for a variety of functional benefits and ideally can serve as a fiber-rich additive as a source of better quality dietary fiber [28]. Moreover, fruit derived products are an emerging area within functional foods [29]. Mir [30] studied the influence of apple pomace on the chemical, antioxidant and sensory properties of rice crackers. Crackers prepared from 9% pomace level had significantly higher antioxidant properties and dietary fiber. 9% pomace level cracker expressed significantly higher radical scavenging activity, total phenolic and flavonoid content. The pomace based cracker contained higher dietary fiber especially insoluble fiber than cracker without pomace. Fruit or vegetable pomace can be incorporated in ready-to-eat snacks and breakfast cereals helping overcome nutrient shortfall in modern convenience food [31]. Paraman [32] used supercritical fluid extrusion to process apple pomace and cheese whey into nutrient-enriched, shelf stable puffed extruded with low density puffed and enriched in dietary fiber and natural antioxidants.

## The characteristics and utilization of apple peel made by separation pre-pressing technology

About thousand metric tons of apple peels are wasted in apple processing plants every year [33]. Previous studies have reported that about 80% of polyphenols are concentrated in apple peel [34]. Moreover, the apple peel has higher total antioxidant capacity (five-to six-fold) than apple flesh and higher total flavonols (six-to seven-fold) than apple pomace [35,36]. Polyphenols isolated from frozen and dried apple peels were studied as potential natural antioxidants to stabilize omega-3 polyunsaturated fatty acid enriched fish oil [37]. The flavanol-rich fractions inhibited fish oil oxidation by 40%-62% at a total phenolic concentration of 200 µg/ml showing higher inhibition of lipid oxidation compared to  $\alpha$ -tocopherol, butylated hydroxytoluene. Apple peel phytochemicals also have cardioprotective anticancer properties, revert the progression of the thermogenesis and affect cholesterol [38-41]. As a rich source of flavonoids, apple peel has a potential to act as an ACE [42]. Triterpenoids especially, ursolic acid present in apple cuticular wax are also integral parts of the human diets as an important group of phytochemicals [43]. Screening plant material in the search for triterpenoid-rich plant tissues has identified



Figure 3: Apple flesh was dried by vacuum paddle drying method.



Figure 4: Broccoli, red-fleshed apple were processed by the separation pre-pressing technology.

fruit peel and especially fruit cuticular waxes as promising and highly available sources. Apple cuticular waxes are receiving more and more attention because of biologically active triterpenoids [44]. Mueller [45] confirmed that triterpenoids present in apple peel and  $\beta$ -damascone may be helpful in the treatment of IBD as nutrient supplements. Xiangjiu and Rui Hai [46] isolated triterpenoids from apple peels and confirmed that triterpenoids have potent in anti-proliferative activity and suggested that it may be partially related with the anticancer activities. Triterpenoids are being evaluated for use in new functional foods, drugs, cosmetics and healthcare products. Apple peel is expected to be developed to triterpenoid-containing products.

Wolfe and Rui Hai [47] used different drying methods to dry apple peel and proposed that apple peel can be a valuable food ingredient because they could be dried and ground to a powder without large losses of phytochemicals. According to their study, peel blanched for 10 s and freeze-dried before being ground to a powder would make the most

stable product. Apple peel powder can be added to cereals, granola bars and sports bars assisting in the prevention and management of chronic diseases [47,48].

#### The characteristics and utilization of apple seeds made by separation pre-pressing technology

The share of seeds in apples can be as high as 0.7% of fresh fruit, which could be used as a valuable source of bio-compounds [49]. In the traditional process of apple juice, 60% of the apple seeds were dispersed in the apple juice and the 40% seed wrapped in the apple pomace, which resulted the low utilization of apple pomace and caused safety problems [50]. In the separation pre-pressing, the separation rate of apple seeds was 95% and the purity was 98% which improved the utilization of the apple pomace and apple seeds greatly.

Plant oils, especially cold-pressed, have an important role in human daily diet. Gornas [51] demonstrated that seed oils recovered

from apple juice industry by-products are a promising source of bio-compounds, particularly unsaturated fatty acids such as oleic and linoleic acids, which represent approximately 90% of the total fatty acids, as well as phytosterols, mainly  $\beta$ -sitosterol. They are not only a source of triglycerides and unsaturated fatty acids, but also a valuable source of bio components such as phenolic compounds, squalene, sterols, carotenoids, lignans and tocopherols, which could be used in food and pharmaceutical industries as a promising alternative to widely used sources [52-55].

Apple seed is also a rich source of polyphenols, especially phloridzin, which can inhibit lipid peroxidation [56-59]. In addition to its antioxidant activity, phloridzin has been recognized as a potential anti-diabetes agent [60]. There is also study demonstrating that apple seeds might be fully exploited for the recovery of colored preparations displaying antioxidant activities which may represent an interesting alternative to synthetic dyes [61]. Overall, seeds are one of the valuable parts of apple fruit by-products, which could be successfully applied in food pharmaceutical and cosmetics industries.

## Conclusion

Apple is one of the most popular fruit crop in the world and China is a big country of concentrated apple juice. Every year nearly a million tons of apple pomace cannot effectively utilized. Due to the growing trend of replacing synthetic substitutes with their natural counterparts, changing consumer expectations and environmental protection concerns, separation pre-pressing makes it possible that making use of the whole apple into natural ingredients and provides new opportunities to manufactures to sustainably transform their byproducts into value-added products. Companies can make best use of the whole apple to process related products without any waste, which can not only obtain natural bio-components, but also make tangible financial benefits. Innovation and practice of separation pre-pressing and whole apple utilization also can be used in other fruits and vegetables. Broccoli, red-fleshed apple were processed using this technology (Figure 4). Juice and flesh are separated well making sure good quality of juice without losing a lot of nutrition. This can be a good example of the management of by-products generated by fruit-vegetable industry.

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