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Industrial applications of apple pomace and orange peel to develop incremental products

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Abstract
The development of a sustainable strategy for handling fruit waste has become critical. Apple pomace and orange peel are considered industrial waste (20-25%) that has very minute or no commercial worth and are being frequently utilized either as animal feed or go back to ranches for fertilizing the soil. Because of their favorable nutritious and functional properties, these fruit wastes can be transformed into a promising source of functional composites. Different important and functional components including, bioactive components such as polyphenols, dietary fibers, essential oil, flavors, and many other components have been recognized in the fruit leftover. Because of their functional properties, apple pomace and orange peels are used in a wide array of bakery products like bread, cakes, muffins, and cookies. Apple pomace and orange peels can be used as effective functional ingredients in meat, dairy, confectionery, and beverage products. The present review intends to summarize all utilization modes of apple pomace and orange peel in different food industries and also reviewed the essential bioactive components extraction from the apple pomace and orange peel. Thus, it will open up the doorways to promote effective waste management for the industrialists to earn profit by developing value-added products.

Keywords: apple pomace, orange peel, functional ingredient, extraction, bioactive components, limonene

Introduction

Fruits assume vital parts in human eating regimens and as far as health is concerned, the interest in such food commodities rises endlessly. Though, during fresh consumption and food processing massive quantities of numerous fruit waste by-products such as peel, core, and injured fruits are generated (Zahid *et al*., 2021) [50]. During the post-harvest handling and industrial processing, fruits are discarded as wastes, that contain roughly 10–20% peel. Because of their favorable nutritious and functional properties, these fruit wastes can be transformed into a promising source of functional composites. Different important and functional components including, polysaccharides, polyphenols, dietary fibers, and flavor components have been recognized in the fruit peels. Apple (Malus Domestica) is widely cultivated in moderate areas of the world and is the world's fourth most devoured fruit crop following oranges, bananas, and grapes.

(Table 1) describes the scientific classification of apple and orange. In the year 2013, it was accounted that the worldwide average total apple utilization surpassed nine kilograms and has since expanded (Lyu *et al*., 2020) [24]. As per the most recent report by FAO, in 2017, apple's yearly global production has expanded by 48% throughout the most recent twenty years and arrived at 83.1 million metric tons.

Table 1: Scientific Classification of Apple & Orange

Orange *(Citrus sinesis)*		**Apple *(Malus domestic)***	
Kingdom	*Plantae*	Kingdom	*Plantae*
Phylum	*Mangoliophyta*	Phylum	*Mangoliophyta*
Class	*Mangoliopsida*	Class	*Mangoliopsida*
Order	*Sapindales*	Order	*Rosales*
Family	*Rutaceae*	Family	*Rosaceae*
Genus	*Citrus*	Genus	*Malus*

Asia represented 65.4% of the worldwide production as the first place for apples, while China delivered 41 thousand metric tons. Other significant producers are the USA, Turkey, and Poland, addressing 6.2 percent, 3 percent, and 3.6 percent of total global output, correspondingly (Lyu *et al*. 2020) [24]. Even though the worldwide apple yield continues to grow, the proportion of apple utilization stays moderately steady. The consumption of fresh apples represents, 70 percent to 75 percent of global production, whereas the remaining (25% to 30%) managed a variety of value-added food items such as jams, alcoholic beverages, juices, and dried fruits (Shalini & Gupta, 2010) [37]. Nevertheless, squeezed apple is as yet the utmost requested apple item, representing 65% of the aggregate sum of processed apples.

Usually, during juice production, almost 75% of apple fresh weight is generally extracted as juice, and the rest is gathered as a food waste, which is supposed to be apple pomace (Vendruscolo *et al*., 2008) [42]. Fruit pomace is a leftover that remains after the extraction of juice from fruits and contains around 20–25% weight of fresh fruit. Globally, it is expected that almost many thousand metric tons of apple pomace are produced annually, which is likely to rise in the future.

Table 2: Region-wise production of Apple Pomace

Country	Quantity Produced (Thousands of tons)
Germany	250
USA	27
Brazil	13.75
India	3-5
Iran	97
Japan	160

Shalini & Gupta, 2010 [37], Pirmohammadi *et al*. 2006 [34]

Pomace is considered an industrial waste that has very minute or no commercial worth and is frequently utilized either as animal feed or go back to ranches for fertilizing the soil. As a fruit part, pomace can be changed into different constituents for food applications (Yu & Ahmedna, 2013) [48]. For example, apple pomace, which comprises fruit peel, core, and pulp, can be changed over into different food and industrial constituents like pectin, enzymes, citric acid, bio-adsorbents, and biofuels. Orange peels are high in bioactive chemicals that function as antioxidants and nutraceuticals (Omoba *et al*., 2015) [33]. Citrus syneresis is a well-known fruit crop that is high in antioxidants, minerals, and vitamins. It is mostly processed into juice, leaving around 20% of the peels as waste, which is susceptible to microbial development and hence pollutes the environment (Boukroufa *et al*., 2015) [5]. An earlier study found that these peels are high in dietary fiber and phenolic compounds, as well as having strong antioxidant capabilities (Omoba *et al*. 2015) [33].

Moreover, the nutritional and bioactive potential of apple pomace and orange peel aside, food security is also a concern. The availability of sufficient and nutritious food is necessary in order to lower the increasing rates of disease and economic burden. Instead of wasting apple pomace and orange peel, their utilization in preparing healthy and nutritious food products can be a wise strategy to minimize problems associated with food security. However, the review focuses on the summary of all utilization modes of apple pomace and orange peel in different food industries and the extraction of essential bioactive components from the apple pomace and orange peel.

Composition and nutritional value

1. Apple Pomace

Apple pomace is a heterogeneous combination comprising primarily 95 percent of tissue and skin, along with little extent of stems 1 percent and seeds 2-4 percent. Despite the variations in content, nutrients are rich in apple pomace. It is a decent source of phytochemicals and comprises substantial quantities of carbohydrates just limited amounts of proteins, minerals, and vitamins (Shalini & Gupta, 2010) [37]. The carbohydrates in apple pomace contain predominantly insoluble sugars such as cellulose (12.79%), hemicellulose (0.72 to 4.36%), and lignin (1.53 to 2.35%), with simple sugars including glucose (18.1 to 22.7%), galactose (6 to 15%) and fructose (23.6-44.7%) (Dhillon *et al*., 2013) [12]. Apple pomace was found to be a rich source of minerals, like phosphorus (0.07% to 0.076%), calcium (0.06% to 0.1%), magnesium (0.02% to 0.36%). Significant amounts of the polyphenols that is, 31 percent to 51 percent, particularly, the flavonols, dihydrochalcones, and cinnamate esters (Will *et al*., 2006) [45].

Moreover, it has already been confirmed that apple-pomace contains a higher concentration of antioxidant compounds like quercetin-glycosides, phloridzin, and other polyphenols with strong antioxidant activity. Thus, apple pomace is of prodigious nutritional benefit, giving health benefits. A few investigations demonstrated that apple-pomace just not only helps to prevent constipation and hypertension, it may also neutralize specific injurious materials in the human body, such as oxidants or free radicals (Bhushan *et al*., 2008) [4]. The presence of such an important composite likewise shows that the apple-pomace has the potential to be employed as a component in the food sector.

Table 3: Nutritional composition of Apple Pomace

Compounds	Quantity (g/100g)	Compounds	Quantity (mg/100g)
Fat	0.26-8.49	Sodium	2-200
Protein	1.2-6.91	Potassium	449
Fructose	11.5-49.8	Calcium	50-150
Glucose	2.5-22.7	Phosphorus	50-950
Pectin	3.5-14.2	Magnesium	20-45
Total Dietary Fibres	26.8-82	Iron	2.4-23
Total Polyphenolics	0.17-0.99	Zinc	0.22-1.5

Yangilar, 2013 [49]; Sudha *et al*., 2016 [40]; Lu *et al*., 2020 [27]

2. Orange Peel

Orange peels are a waste product of orange fruits used for processing. They represent less than five percent of fresh fruit and have hard horny shells containing oily kernels. Concerning orange peels, it contains 1.41%, 2.1%, 3.33%, 6.78%, and 86.38% protein, lipids, fiber, ash, and carbohydrates, respectively. Although, there is a variation in chemical profiling of Citrus peel reported from different pieces of literature. Citrus peel, the primary waste, is a good source of molasses, pectin, and limonene and is usually dried, mixed with dried pulps, and sold as cattle feed. Industry and fruit merchants process citrus reticulata into juices, and 30–34% of the kinnow peel is obtained as a significant processing by-product. This kinnow peel is found to be a rich source of health-beneficial compounds including vitamin C, carotenoids, and polyphenolic antioxidants (Anwar *et al*., 2008) [3].

Consumption of Apple Pomace and Orange Peel

Till today, the exploration of the health risk of apple pomace and orange peel is as yet inadequate and needs more research. Previous research showed two possible hazards associated with the utilization of apple pomace i.e. native plant toxins and pesticide intake. Amygdalin present in apple seed, which might instigate severe intoxication of cyanide, has increasingly become the focus of plant-toxin research. Though, ongoing investigation has revealed that the degree of apple-seeds amygdalin is by and large harmless for the utilization of humans. Roughly, utilization of 0.8kg of apple pomace, which is exceptionally improbable to occur, produces intense cyanide poisoning among people (Skinner *et al*. 2018) [41]. The Environmental Protection Agency (EPA) of the USA announced both thiophanate, and carbendazim were not extremely hazardous. While the evaluation of pyrimethanil is still ongoing, the EPA has determined that a comparable fungicide, cyprodinil, is safe. Furthermore, naphthaleneacetic acid, and diphenylamine, are the plant-growth residue regulators that have been reported and cause no damage, and are not harmful, according to the EPA of the USA (Lyu *et al*., 2020) [24].

Apple-pomace Utilization

Apple-pomace, on the other hand, is recognized as a prodigious valuable component to be used in various foodstuffs, because of its greater amount of dietary fiber, bioactive composites, and many additional components. Though, when apple-pomace is added to food items, particularly quality characteristics suffer. Thus, apple-pomace use as a functional component is comparatively low, and all these quantities must be cautiously checked.

Bakery food products

People have been devouring various bakery store goods such as cakes, cookies, and bread for several decades and are broadly acknowledged. Apple-pomace utilization in different bakery-food items is thought to increase the dietary fiber content and health aids. Attempts were made in recent years to use apple-pomace as a nutritional fiber content supplement in bread production (Lyu *et al*., 2020) [24]. A research found that 2%, 5%, 8%, and 11% apple-pomace were used in the production of wheat bread. The outcomes revealed that the loaf of a bread mass increased by 3 percent and 7 percent in the neutralized and un-neutralized dough, respectively. when the pomace level increased from eleven percent. In un-neutralized and neutralized doughs, the reduction in the loaf size was 42.8 and 26.6 percent, respectively. The color of the crust and bread toughness were observed to improve as the pomace content was increased. The usage of apple pomace to various extents (5, 10 and, 15%) in the manufacturing of cake (Masoodi *et al*., 2002) [30]. They reasoned that when the pomace level increased, the volume of the cake decreased significantly, whereas the particle size showed a contrary pattern. Furthermore, notable intensifications were seen in shrinkage and consistency index, however, there were no huge differences somewhere in the range of 10% and 15% treatments. Additionally, different studies reported the utilization of apple pomace as an alternative to wheat flour in muffins and biscuits. It was also discovered that muffins having apple pomace below twenty percent were stable in form and rated highly on sensory evaluation for flavor, texture, and color (Sudha *et al*., 2016) [40].

The evaluation of crust and crumb color, on the other hand, indicated a significant reduction after the replacement level above 20%, as it went from creamier yellow to brown. Mir *et al*. (2017) [31] developed a gluten-free wafer using brown rice flour and 3 percent, 6 percent, or 9 percent apple-pomace. The addition of pomace altogether rises the minerals substances like chlorine (Cl), and potassium (K), and also the antioxidant potential; TDF, and TPC were also improved. As a result, apple-pomace might be regarded as a nutritious as well as a functional component in bread items.

Apple Pomace Used in Extruded Food Products

The nutritional value of extruded snack products has proven to be enhanced by adding apple pomace without causing any noticeable effects on the physical properties of snack products (Stojceska *et al*., 2010) [39]. Singha and Muthukumarappan (2018) [38] developed an extruded snack based on apple-pomace using defatted soy-flour and corn grits. The bulk density, antioxidant potential, and the TPC elevated tremendously as the increase in pomace level from 0% - 20%. Expansion rate was observed to upsurge below 5% treatment whereas demonstrating a contrary pattern at 10% and 20% expansion levels. On the other hand, corn-starch-based extruded products with an apple-pomace concentration of 15 and 30%, reported the opposite results. By the incorporation of 15% pomace, higher early and constant expansion indexes were attained although the mechanical energy price was lesser (Masli *et al*., 2018) [29].

Confectionary and Dairy Products

Apple pomace is regarded as an ideal constituent to be used in confectionery products manufacturing, because of its higher level of flavoring compounds and pectin. Confectionary product, jelly was developed via utilization of apple pomace, and quince fruit puree. Hussein *et al*. (2015) conducted a similar study on an apple-pomace jam created from various fruit byproducts like an apple-pomace, and mandarin peels, carrot, and banana peels (Hussein *et al*., 2015) [18].

Another research found that incorporating apple pomace into blended yogurt allowed for a higher amount of pomace to be added 3 percent and resulted in a significant reduction in syneresis as well as an increase in thickness, cohesiveness, and solidity of the medium after twenty-eight days of cold storage. Another study addressed the probable use of an apple-pomace in yogurt and other dairy products such as natural preservatives, texturizers, and a good source of nutritional fiber, and phytochemicals (Wang, 2017) [44]. Due to the absence of a comprehensive study on the rapid exploitation of an apple-pomace in dairy food items, a detailed investigation is necessary to investigate the potential as well as satisfactoriness of that food items.

Meat Products

A substantial portion of current research focuses on the use of an apple-pomace in meat commodities to ameliorate the lack of nutritional fiber in meat. Attempts have been undertaken in red-meat products such as mutton nuggets (Huda *et al*., 2014) [17] and mutton goshtaba, & chicken byproducts like chicken sausages, and nuggets. Furthermore, the buffalo-meat patties were developed in which the quantity of meat was replaced by 2 to 8 percent of an apple-pomace (Lyu *et al*., 2020) [24]. The fat content, moisture level, and crude fiber level were shown to have a substantially positive relationship with substitution level. Comparable patterns were seen in the thickness of the patties and cooking yield, as well as textural attributes such as solidity & durability. When the replacement level approached 6%, viscidity and springiness decreased. A similar amount of an apple-pomace replacement for the bison-sausages, and had comparable findings (Younis & Ahmad, 2015) [47].

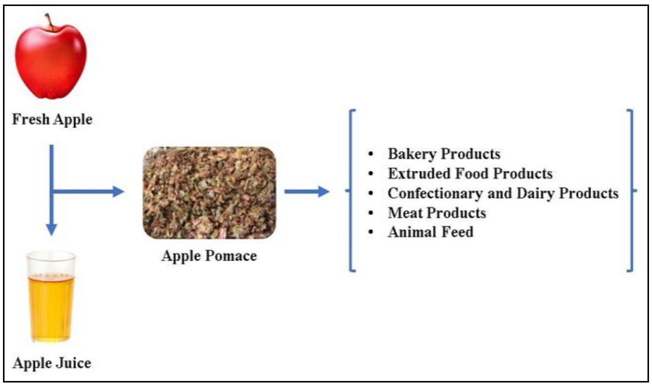

Fig 1: Utilization of Apple and Apple Pomace

Utilization of apple pomace in the food & beverage industry as a Catalyst

1. Production of Alcoholic-liquors

Since apple-pomace fermentation has been utilized to make ethanol due to its low land need and inexpensive cost. The standard ethanol production process is published for robust brewing using apple-pomace separately, or apple-pomace and molasses mixed substrate (Lyu *et al*., 2020) [46]. In addition, immediate saccharification & fermentation (SSF) have been mentioned in the ongoing study. Apple-pomace is used in the food business to make moderate alcoholic drinks, which are likely to improve their flavor (Li *et al*., 2015) [23].

2. Miscellaneous Uses

Madrera *et al*. (2015) used Sacch. cerevisiae, Hanseniaspora uvarum, and valbyensis, and a blend of Sacch. cerevisiae and an introduced enzyme to examine unstable compounds generated during an apple-pomace fermentation (Madrera *et al*., 2015) [28]. There is a sum of 132 unstable compounds from various chemical families that were identified as strain subordinates. The findings indicated that the fermented apple-pomace may be employed as a natural flavoring ingredient in beverages through exfoliation or fermentation. The mixing qualities of apple pomace and oat grain bran were investigated by (Huc-Mathis *et al*., 2019) [20]. To get a 50/50 (weight/weight) oil in water suspension, jojoba, myritol, and rapeseed oils were combined. The results showed that apple pomace can best support rapeseed and myritol oil emulsions. In this regard, apple pomace might be seen as a possible balancing out representative, and its interactions with other prevalent components in food items need more investigation.

Apple Pomace Bioactive Component Extraction

The foremost useful bioactive composites are extricated from apple pomace. These essential apple pomace constituents, gelatin, phenolic, and fiber, can be extracted and employed in many culinary items. Because they are high in nutrient content, such components can supplement meals which include, cider, meat items, and cookies. Nonetheless, investigations on the extractions of these beneficial components focus mostly on extraction advancements, with a limited number of studies on the usage of such components in different food items (Lyu *et al*., 2020; Bhushan *et al*. 2008) [4] [24].

1. Extraction of Pectin

Pectin is a dissolvable sticky fermentable fiber that is extensively used in food manufacturing as an emulsifier, gelling agent, and thickener in a wide range of culinary goods including candy, beverages, and baked jellies, and yogurts (Shalini & Gupta 2010) [37]. Apple pomace use for pectin extraction is believed to be one of the most feasible ways, and it has been used in many sectors such as cosmetics and pharmaceuticals. Because apple pomace is among the principal organic origin of pectin, obtaining pectin from fruit has indeed been considered a viable way of using an apple-pomace (Will *et al*., 2006) [45].

2. Extraction of Fiber

Even though apple-pomace may be utilized directly as a key component in foods, and pomace extract is likely to be more advantageous in terms of fiber enhancement. Fiber extract is used to provide dietary fiber such as gelatin, lignin, and cellulose in a wide range of culinary and medicinal products. Furthermore, obtained fiber from apple-pomace has the potential to be used as a fat substitute in meat items., which is reported to increase rheological characteristics and emulsion stiffness (Lyu *et al*., 2020) [24]. Raw, chicken sausages with minimal fat developed through slightly substituting (5 percent & 10 percent of the fat with 1 percent and 2 percent) of apple pomace fiber content. According to the data, increasing the replacement quantity resulted in a considerable drop in both fat content and caloric energy. Similar patterns, such as cooking loss and fat division, arose in emulsion consistency. Thus, a fiber derived from apple wastes has already been effectively included in food items to manage the utilization of fat.

3. Extraction of Phenolic Content

Phenolic compounds from various plant sources, including apple pomace, are influential antioxidants, and antioxidant activity is linked with the type and concentration of phenolic compounds in the food medium. Many investigations have detailed high antioxidant activities (DPPH) for apple pomace (that is, 2.09 to 3.74 mg TEAC/g dry weight sample powder. Though these amounts are firmly predisposed by the extraction technique and situations, frequently do not address the actual antioxidant activity of this byproduct (Perussello *et al*., 2017) [35]. Also, the substance of phenolic compound relies upon apple assortment, cultivate condition, and development constraints, which are generally significant for extracting polyphenols. However, the percentage of phenolic compounds in apple pomace was high, the free phenolic composite was little which was not stable, and the greater part of phenolic compounds existed in the bound form with protein, lignin, and polysaccharides. The use of these polyphenols should influence the organoleptic possessions, like color, odor, and flavor, and the antioxidant capability of food items. Subsequently, polyphenols could also be utilized as beneficial components as well as natural antioxidants (Rana *et al*. 2015) [36].

Orange Peel consumption as Functional Ingredient in Food Processing Industry

1. Baking industry

The statistics disclosed that the OP addition for biscuits in flour has increased the carbohydrate ash and fiber content from 51.49 to 57.8%, 2.01 to 2.97% & 0.25 to 0.54% respectively. It is also noted that the energy values for food have been also increased from 466.29 to 507.95 kcal. But there is a reduction noted in the values for protein, moisture, and fat content which are 16.79 to 14.49%, 5.16 to 2.65% & 24.31 to 21.4 % respectively. An increase in the total content of DF is noted. DF is very efficacious in the digestive tract and is a major component of plant food (Liu, 2013) [26]. DF daily intake advocated per person is 25-35g (Buttriss and Stokes, 2008) [6]. The consequences we obtained disclosed that the soluble dietary fiber, total dietary fiber, and insoluble dietary fiber content have been increased and the values are 3 to 3.84%, 4.84 to 5.27% and 1.44 to 1.84% respectively. These are also explained by the abbreviations SDF, IDF & TDF. The increase in the antioxidant properties is followed by OP swapping. The sample of biscuit having OP substitution of around 20 percent has the way up flavonoid content 8.12 mg QE per gram, phenolic content in total that is 1.87 mg GAE/g and scavenging ability of ABTs radical is 2.19 mMo1 TEAC per gram. Whereas the biscuits sample without OP contains the minimum values of ABTs scavenging properties, total phenolic content & flavonoid content is 1.17 mol TEAC per gram, 5.84 mg GAE per gram, and 1.20 mg per QE per gram respectively. As the level of orange peel rises the crude fiber content values also increase. This consequence was in concurrence with the report by Ajila *et al*. (2010) who observed the fiber content in macaroni increased with the addition of the Mango peel (Ajila *et al*., 2010) [1]. As the OP substitution rises or increases the content of protein in biscuits decreases (Table 4)

2. Orange peel as a source of enzymes

In the production of enzymes, the utilization of citrus peels is one of the prime areas specifically for pectinolytic enzymes. Pectic substances are hydrolyzed by pectinases which is a heterogeneous group. In the current era of biotechnology, the enzymes are of notable importance because of their use in different solicitation in the extraction of different fruit juices followed by different operations such as extraction of coffee, tea, vegetable oil, scouring of cotton, treatment of wastewater, fermentation of coffee, degumming of plant fibers, alcoholic beverages, bleaching in the paper industry, additives in poultry feed and indifferent food industries (Jayani *et al*., 2005) [21].

Pectic enzyme is engendered by the waste of citrus used as a carbon source when *Aspergillus foetidus* ATCC 16878 is grown beneath solid-state fermentation which shows activity at up to 1600 to 1709 U per gram after thirty-six hours of culture.

Extraction of Bioactive components from Orange Peel:

1. Flavonoids

Flavonoids symbolize 2 benzene rings C6 and C3 joined with each other in a linear chain at C position with the carbonyl. It contains benzopyrone and phenyl structure. Flavonoids are nonnutritive agents and play a pivotal role in the prevention of chronic. The Flavones of O-methylateglycones include tangeretim and nobiletin, and the citrus family incorporates glycosides which are named naringin and hesperidin, the flavones, and tangerine are two unsavory ply methoxylated flavones (PMFs) (Li *et al*., 2015) [23].

Abi-atherosclerosis activities are anti-inflammatory, anti-carcinogenic, antioxidants, and anti-inflammatory. Individual Flavonoids structure highly respond to anti-inflammatory activity (Manthey *et al*., 2001) [32]. For example, hydroxyl, and flavones may have 40 Oh and 30 - 40 surrogates on the B ring, respectively and these are selective lipoxygenase inhibitors. Phosphodiesterase gets an inhibitory effect by flavones with more than 5 methoxy surrogates. (Manthey *et al*. 2001) [32]. In human monocytes LPS induced TNF (a potent inhibitor), PMFs such as nobiletin is utilized.

2. Antioxidants

Due to the presence of phytochemicals the antioxidant characteristics of plant material increase. Those phytochemicals are plant sterol, coumarins, lignin, terpenoids, vitamins, saponin, carotenoids, etc. The extract of orange peel inhibits the effect of lipid oxidation. That's why the purpose of this investigation was to assess the benefits of different solvents i.e., acetone, ethanol, dichloromethane, hexane & ethyl acetate it detects the efficiency of extraction by effective compounds (Hegazy *et al*. 2012) [19]. Kinnow and the extract of rind powder are used to avoid the disadvantages of the use of synthetic anti-oxidants used in meat products. The consequences show that these compounds have a rich source of phenolic compounds and contain free radical scavenging activity to get the citrus powder extracts. These are far safer than synthetic ones. Another hearten investigation was done by (Lagha-Benamrouchea & Madania, 2013) [25] to authenticate the byproducts of the orange varieties in respect of leaves and peels which are cultivated in Algeri as a formidable antioxidant.

3. Dietary fiber Extraction

Classification of dietary fiber comprises soluble and insoluble dietary fibers of polymers of plant carbohydrate, poly, and oligosaccharides. For example, resistant starch, cellulose, pectin substances, hemicellulose, gums, insulin, and in a consortium of some non-carbohydrate fractions (Fuentes-Zaragoza *et al*. 2010) [14]. Cereal fruits are used as value-added products in everyday life and vegetable by-products also fall in this category. They contribute to supplying different compounds like essential oils and polyphenols. These things provide an advantage to the consumer economy and producer. For example, from the processing of the citrus peel, we get the residue that is used in further processing.

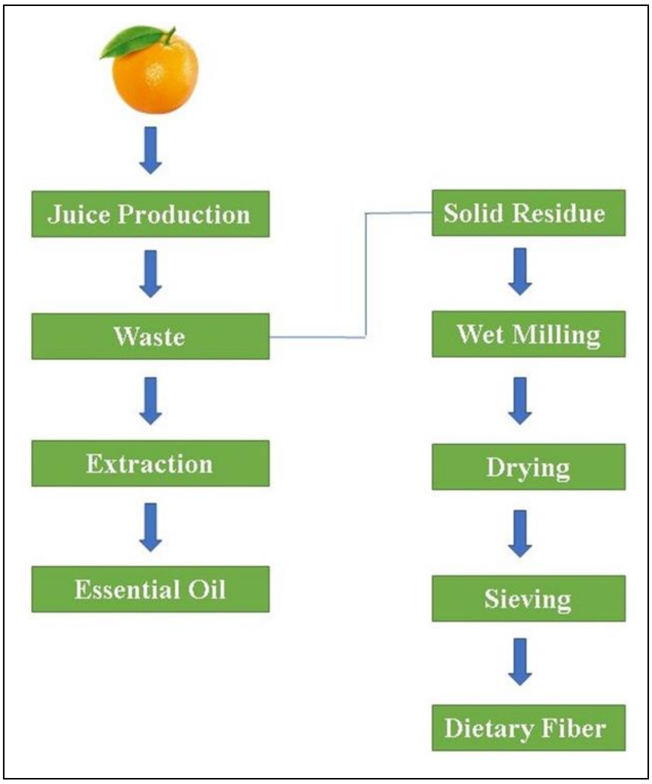

Fig 2: Processing of orange & its peel for essential oil and dietary fiber

Orange peel as Essential Oil source

Several advantageous yet precious bioactive compounds are contained in orange oil which are Pmyrce, Sabinene, Linalool, and b-pinene. Among the extractable fruits or compounds, these are the most augmented products obtained from orange peel waste (Gavahian *et al*. 2018) [15].

In bio-based communities, agricultural waste involving orange peel is scrutinized as an important contingency. Different chemical compounds are proving to be health hazards so trends to use essential oils in different foods are being made (Gavahian *et al*., 2018; Bakhtiary *et al*. 2018) [8, 15]. Orange essential oil is proved to be an auspicious oil prepared within the orange fruit rind that is citrus Sinensis fruit and can be used in different applications in the Food Industry (Farhat *et al*. 2011) [13]. Farming and harvesting time can vary the composition of the essential oil including orange essential oil (Asl *et al*., 2018) [2]. The composition values we get from the extracted orange oil by Gana originated orange compresses of the following compounds such as 1,2-epoxide, 2% carveol, 85% limonene, 3% carvone, 2% linalool (Guo *et al*. 2018) [16]. As stated by Atyla, orange extracted oil prepared by the US originated peels have; 1.5% Linalool, 74% Limonene, 3% Sabinene, 4% p-myrcene. The orange oil we get by steam distillation comprises D-limonene oxide 2.23%, D-limonene 84.05%, b-myrcene 0.88%, a-pinene 0.85% (Bo *et al*. 2014) [9]. It is known as the most customary flavoring agent used in Food Industry such as in ice creams, drinks, etc. The most important and main intrinsic or orange oil is limonene & also used in the pharmaceutical food and cosmetic industries (Gavahian *et al*. 2018) [15].

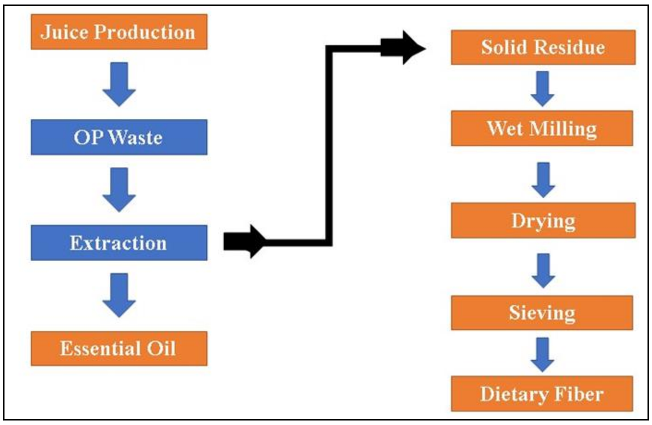

Fig 3: Process of Oil extraction from Orange Peel

1. Orange Peel Oil Extraction Techniques

1.1 Ultrasound-assisted extraction

Due to the cavitation essential oil obtained from the orange peel that is present in the gland-like structures is affected and collapses. Destroying the essential oil's surrounding environment might be interpreted as increased mass transfer, resulting in the simpler release of these volatile molecules. (Li *et al*., 2015) [23]. For extraction of the orange peel essential oils hydro distillation and ultrasound are combined. As a result of this time process is shortened if we compare it with the conventional hydrodistillation procedure. Due to the oxidation process, the extraction of essential oil is mainly affected when subjected to a long-term sonification process.

1.2 Microwave-assisted extraction

Extraction of oil from orange peel can be improved using microwave energy. During use of microwave extraction technique, the oil obtained will be of higher quality and higher quantity as compared to the older hydrodistillation. Standard process situations for MAE of oil from orange were the pressure of 300 Mb, water mixture (1:1.5), and the total time of 20 min for overall extraction which gives 1.8% (dry matter basis) which was greater in number value if compared with hydrodistillation, that is 1.7%. keeping in mind all the circumstances of MAE, we consider it a time-saving process and energy-saving too for the production of orange oil (Bustamante *et al*. 2016) [7].

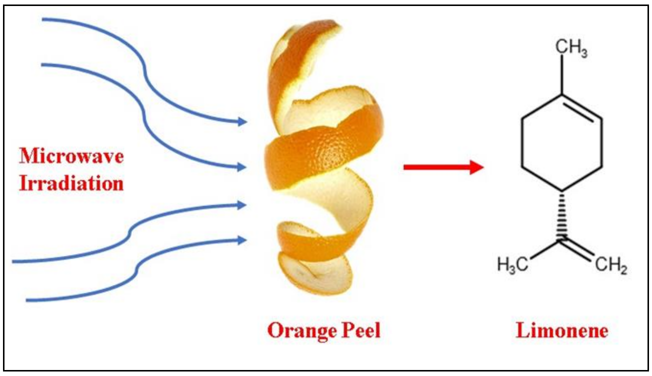

Fig 4: Microwave Assisted Extraction of Limonene from Orange Peel

1.3 Superfluid Extraction

Xhaxhiu and Wenclawiak (2015) [46] evaluated the usefulness of supercritical carbon dioxide extraction of orange peel (extraction temperature: 40 °C, pressure: 200 atm, particle size: 0.05–0.1 cm), flow rate: 1.6 mL min1, and compared it to the UAE (input power 10 W and extraction time 5–60 min (Xhaxhiu and Wenclawiak, 2015) [46]. Discovery suggested that the supercritical extraction process may be preferable than UAE. Comparable, it appears, to traditional extraction in terms of extraction yield and extraction time. Similar, to previous studies on orange peel oil, limonene was found to be the most prevalent component of the extracted essential oils, with concentrations ranging from 89 to 91 percent, followed by valencene, decanal, b-myrcene and pinene, linalool, and valencene. As a result, substituting the old extraction procedure with modern methods like SFE may result in more economically useful orange essential oils. As a result, when compared to inefficient older methods, SFE may be classified as a green extraction technique since it can minimize waste and increase output rate without the use of chemical solvents.

1.4 Enzyme-aided extraction

Cellulase and hemicellulose's main actions include hydrolysis of cell wall components, which enhances cell wall permeability and results in increased yields. Additionally, enzyme treatment reduced the extraction medium's viscosity, helping to break up any potential emulsion systems in order to remove the oil from the aqueous phase. A cellulose enzyme pre-treatment was used in this case to extract essential oils from orange peel. When compared to traditional procedures, enzyme-assisted extraction (EAE) increased orange oil output by a factor of two (Chavez-Gonzalez *et al*. 2016) [10].

Table 4: Different extraction methods to extract limonene

Extraction Method	Temperature	Yield
Solid Liquid Extraction	100-200	2.97% w/w 0.95% w/w
Hydrolysis	55	66%
Soxhlet Extraction	85	100%
Hydro distillation	-	4.5kg
Ultrasound Assisted Extraction	60	32.9 mg/g (97%)
Microwave assisted extraction	110	14.1 wt%
Continuous pilot scale steam explosion system	-	97%

Waheed *et al*., 2020 [43]; Khandare *et al*., 2021 [22]; Dorado *et al*., 2021 [11]

Conclusion

With the changing trends of food security every year, the availability of sufficient and nutritious food is gradually becoming a challenge. On the other hand, food wastage is another problem when the malnutrition is prevailing and access to healthy and nutritious food is becoming difficult. This scenario necessitates the creation of solutions that can fully exploit the potential of apple and orange wastes (pomace and peel) and aid in the attainment of cultural, ecological, and financial gains from such waste residues. Utilization of apple pomace and orange peel in various food industries such as in bakery, meat, beverages, dairy, and confectionery and use as a novel ingredient in developing value-added products to enhance the quality as well as sensory attributes of the products will pave the ways to manage waste. Being a cheap and rich source of different beneficial compounds such as dietary fiber, bioactive compounds, essential oils, etc., and developing other value-added products will be an eco-friendly and sustainable approach to create new economic prospects while designing new functional foods from these wastes. Thus, it will be a wise strategy to manage waste, overcome the needs of healthy food and promote industrial and economic growth as well.

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