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A comparative study on nutritional and functional composition of fresh apple pomace and dried apple pomace powder

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ABSTRACT

Apple pomace is considered a major by-product of apple juice processing, which is generated in several million metric tons worldwide every year. Due to its low recovery rate, it is generally disposed of as waste, resulting in various public hazards and environmental pollution. However, it is a rich source of numerous nutritional and functional compounds such as carbohydrates, phenolic compounds, dietary fibre, minerals, and, organic acids. Therefore, this study was undertaken to study the nutritional and functional composition of fresh and dried apple pomace powder to explore its possibilities of usage in the food industry. The fresh pomace and dried apple pomace powder were subjected to various physio-chemical analysis such as bulk density, tapped density, flow ability (Carr Index), cohesiveness (Hausner ratio), carbohydrates, energy value, total polyphenols, antioxidant activity and, hydration properties. While, the functional characterization was obtained by Fourier Transform Infrared Spectroscopy (FTIR) analysis. The comparative analysis revealed that the moisture content decreased from 80.04% to 8.23 percent, while, the ash content, fat, fibre, protein, carbohydrates, energy value, ascorbic acid, total phenols and antioxidant activity increased significantly from 1.12 to 2.06 percent, 0.63 to 2.39 percent, 4.65 to 20.68 percent, 0.81 to 3.12 percent, 12.75 to 63.52 percent, 12.75 to 290.25 kcal/100g, 6.15 to 12.21 mg/100g, 95.26 to 451.14 percent and 75.21 to 85.37 percent, respectively. Moreover, the FTIR analysis confirmed the presence of carbohydrates, fats, proteins, water, phenols and identified various functional compounds including quinones, organic matter, ethers, lignin, aromatic compounds, oxy compounds and disulphides, etc.

1. INTRODUCTION

Apple (*Malus domestica L*), an important fruit crop belonging to the family Rosaceae, is grown in temperate regions of the world. It is the fourth most financially significant crop in the world after banana, orange and grapes. India ranks fifth in the production of apple in the world after China, USA, Turkey and Poland [1]. At present, the crop is being cultivated in the country in 308-thousand-hectare area with an annual production of 2734 thousand metric tons [24]. Apple is the fourth major grown fruit crop in India in terms of production after mango, citrus and banana. Apple farming are the backbone of the rural economy of eastern Himalaya state (Jammu and Kashmir, Himachal Pradesh and Uttrakhand). Himachal Pradesh is the second largest producer of apple after Jammu and Kashmir, is also known as "Apple bowl of India." The major apple producing districts of Himachal Pradesh include Shimla, Kullu, Kinnaur, Mandi, Sirmaur and Lahaul & Spiti, covering a total area of 112.63 thousand hectares with a production of 446.57 thousand metric tons, annually [23]. Apple is a valuable source of a range of nutrients, which helps promote health and is strongly advised for regular consumption. Numerous organic and inorganic substances, such as carbohydrates, proteins, lipids, dietary fiber, minerals, vitamins, and other phytochemicals, are among the nutritional elements. The nutritional content depends on the crop's physiological growth conditions, variety, soil and climate [21]. The apple fruits used for fresh consumption account for 70–75 per cent of total production while, 25–30 per cent is processed into various value-added products such as juice, wine, jam and dried products [33]. However, apple juice continues to be the most popular apple product, making up around 65 per cent of all apples processed [16]. Apple juice is consumed more frequently since it is a non-alcoholic beverage whose popularity has increased recently because of growing public awareness of its health benefits [25].

About 75 per cent of an apple's fresh weight is anticipated to be extracted as juice, leaving the remainder as waste, which is known as apple pomace [38]. Apple pomace is a strong source of phytochemicals such as phenolics, which have high antioxidant activity, as well as total carbohydrates, proteins, fiber fat, ash, vitamins and minerals [7], [19], 6]. Therefore, apple pomace has higher nutritional content and more health-promoting components than processed products like juice, nectar, and other beverages. Additionally, the phytochemicals in apple pomace are effective at lowering cholesterol and lipid oxidation, as well as the prevalence of chronic illnesses like cancer, diabetes, and heart disease [34], [39]. Considering into account the massive output of juice, several million metric tons of apple pomace is produced worldwide each year [16]. The usage of waste has become one of the major challenging aspects around the globe owing to the generation of large quantities of by-products such as peel, seeds, unwanted portion, etc. The most popular method for disposing of this by-product is to dump it directly into the soil in a landfill, but owing to seasonal demand and huge volumes, factories now have difficulty disposing of waste in a timely and efficient manner. The high amount of waste because of high BOD (250–300 g/kg) of uncontrolled fermentation leads to environmental pollution by promoting biogas generation and uncontrollably releasing methane into the environment [11].

In India, less than one percent of the apple pomace is being used for animal feed or dry goods. Apple pomace, due to its high concentration of nutrients, is being used for extraction and isolation of nutrients, such as dietary fiber, pectin, antioxidants, and polyphenols, for use as purified food ingredients. Apple pomace is typically used for animal feed since it is a low-cost waste usage method and may also be used to produce bioethanol and fuel. According to safety tests, apple pomace is a safe animal feed additive with pesticide concentrations below those that are acceptable for ingestion by humans [33]. The commercialization of apple pomace for human consumption calls for additional research focusing on standardized methods of nutrient reporting, mechanism studies, and human clinical trials. The positive effects of this by-product in health could be recognized as the reduction in gastrointestinal problems, weight management lowered the risk of coronary heart diseases, better glycemic control, improved serum lipid

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concentration, improved immune function, lowered blood pressure and reduced likelihood of certain types of cancer. To fully harness apple pomace's nutritional potential, numerous researchers have recently concentrated their efforts on using it to create novel functional products. Many of the bioactive substances and dietary fiber found in apple pomace can be used as ingredients in the bakery, extruded, meat, confectionary, dairy and beverage industries. This will not only improve the functional value of the products but will also improve the way the pomace is being used, reducing waste and promoting the development of innovative products.

2. Materials and Methods

2.1 Preparation of Apple pomace flour

Fresh apple pomace was procured from the canning unit Department of Food Science and Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The pomace was treated with potassium metabisulphite (1000 ppm) and dried in a cabinet drier at 50 ± 2°C for 24 h. Dried pomace was then ground in a Willey grinder and passed through 30 mm mesh screen sieve (500 µm). Ground apple pomace was packed in a polyethylene bag, labeled and kept for storage in a cool and dry place.

2.2 Physical-chemical characteristics and functional properties of fresh and dried apple pomace

2.2.1 Physical and functional charateristics

2.2.1.1 Bulk and tap density g/cm³

Bulk and tap density were determined by the procedure followed by the methods of [26], [35].

2.2.2 Flowability and cohesiveness

Flowability and cohesiveness of the powder were evaluated in terms of Carr index (CI) and Hausner ratio (HR) was suggested by [35]. Both CI and HR were calculated from the bulk and tapped densities of the powder as shown below (Eq. i and ii) and classified according to the following table.

$$CI = (\rho \text{ tapped} - \rho \text{ bulk}) / \rho \text{ tapped} \qquad \text{.......... (i)}$$

$$HR = \rho \text{ tapped} / \rho \text{ bulk} \qquad \text{............(ii)}$$

Table 1.1: Flowability, Hausner ratio and Cohesiveness properties of apple pomace, whole wheat and red rice flours

Carr´s index (%)	Flowability	Hausner ratio	Cohesiveness
<15	Very Good	<1.2	Low
15-20	Good	1.2-1.4	Intermediate
20-35	Fair	>1.4	High
35-45	Bad		
> 45	Very Bad		

Classification of the flowability and cohesiveness of the powder based on the CI and HR values [2].

2.2.3 Hydration properties (g/g)

Hydration properties viz. water holding capacity (WHC) were determined by the procedure followed by [13].

2.2.4 Oil absorption capacity (g/g)

Oil absorption capacity (OAC) was determined by the procedure followed by [13].

2.3 Chemical characteristics

2.3.1 Proximate analysis (%)

Moisture, Ash, Crude protein, Crude Fibre, Crude fat content was determined by method described by [27].

2.3.2 Carbohydrate (%)

The total carbohydrate content as per cent dry weight basis was determined mathematically suggested by [3], using the formula:

Total carbohydrate (%) = 100 - (% moisture content + % ash content + % crude protein + % crude fat + % crude fibre)

2.3.3 Energy value (kcal/100g)

Energy value of the sample was measured in bomb calorimeter (Model Toshiwal DT-100) suggested by [17].

2.3.4 Total soluble solid (°B)

Total soluble solids (TSS) were determined by the procedure given by [27], by using hand refractometer (Model Erma, Japan).

2.3.5 Titrable acidity (%)

The titratable acidity of the sample was expressed as per cent citric acid suggested by [27].

2.3.6 Total solid (%)

Total solid was determined by the procedure given by [27].

2.3.7 Ascorbic acid (mg/100g)

Ascorbic acid content was determined by the method described [27], by using 2, 6-Di-chlorophenol-indophenol visual titration method.

2.3.8 Sugar content (%)

Total sugars and Reducing sugar content of samples was determined by [20], volumetric method.

2.3.9 Pectin (%)

Pectin content from apple pomace was determined as calcium pectate using the gravimetric method suggested by [27].

2.3.10 Total polyphenols (mg/100g)

Total polyphenol content of samples was determined by the method given by [5]

2.3.11 Antioxidant activity (%)

Antioxidant activity of sample was estimated using the method described by [4].

2.3.12 Fourier Transforms Infrared Spectroscopy

FTIR spectra analysis (Shimadzu 8400S FTIR spectrometer, equipped with KBr beam splitter) suggested by [37].

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2.4 Statistical analysis

All analyses were performed in five replicates of observation and the results are expressed as the mean ± standard deviation (SD). ANOVA was performed and means were compared by t-test. P value < 0.05 was considered significant.

3. RESULTS AND DISCUSSION

The result and discussion were recorded on the basis of five observations of analysis, data is obtained and presented as result, which is in line with various previous research are presented in Table 1.2 ,1.3 and fig. 1.1, 1.2.

3.1 Physical and functional properties

The particle size of flour plays an important role during the digestion of food in the digestive tract i.e., transit time, fermentation, fecal excretion. [10]. The results in Table 1.2 show that all three-flour particle sizes were less than 150 µm and the lowest per cent was considered in the particles gathered than 150 µm. The range of particle size depends on the type of carbohydrate (polysaccharides) present in the foods, and their processing method as given by [14]. The bulk density and tapped density of apple pomace powder was recorded 0.68 g/cm³ and 0.77 g/cm³, respectively. A similar value of bulk density for apple pomace powder was also recorded by [31], using a cabinet tray dryer.

The value of the Carr index and Hausner´s ratio for apple pomace powder was recorded as 11.51 and 1.13, respectively. It is evident from the values of the Carr index that apple pomace powder showed excellent flowability characteristics, whereas the value of Hausner´s ratio that apple pomace powder showed exhibited intermediate cohesiveness. Similarly, water holding capacity and fat absorption capacity of apple pomace powder was recorded as 3.23 g/g and 1.33 g/g, respectively. Similar result in the value (3.39–4.6 g/g and 1.3–2.24 g/g) was observed by [22], [12], in apple pomace powder.

Table 1.2: Physical and functional properties of apple pomace powder

Parameter	**Mean ± SD**
	Apple pomace powder
Particle size distribution (%)	
200µm	19.92 ± 0.00
170µm	10.04 ± 0.00
150µm	6.88 ± 0.00
<150µm	63.16 ± 0.00
Bulk density g/cm³	0.68 ± 0.01
Tapped density g/cm³	0.77 ± 0.02
Carr´s index %	11.51 ± 0.02
Hausner ratio	1.13 ± 0.01
Water holding capacity (g/g)	3.23 ± 0.04
Fat absorption capacity (g/g)	1.33 ± 0.03

3.2 CHEMICAL CHARACTERISTICS

The moisture content of apple pomace was reduced from 80.04 percent (wet weight basis) to 8.23 percent (dry weight basis) within 24 h, using 50 ± 2 °C forced-air cabinet drier. Similar results were reported by [15]. Although the ash content of apple pomace was increased during drying from 1.12% to 2.06 percent wet weight basis to dry weight basis, respectively. Similar results of ash content range (2.10 to 2.70 %) in solar and tray dryers in different temperature ranges, respectively [28]. Similarly, crude fat content of apple pomace was also increased on a wet weight basis to dry weight basis in (0.63% to 2.39 %) respectively. Similar findings were reported by [28]. Further the crude fiber content of apple pomace was observed as 4.65 percent to 20.68 percent in wet weight basis to dry weight basis in 24 hrs, respectively, this might be due to increase in dry matter content of pomace during drying. Similar result was observed by [8]. The protein content also increased after drying was recorded as 0.81 percent and 3.12 percent in apple pomace on a wet weight basis and dry weight basis, respectively. Similar results were recorded by [18], in pumpkin fruits, the protein content increased from 2.61 percent to 13.78 percent in fresh fruit to dry powder, respectively.

The value of carbohydrate content and energy values were found highest in dry apple pomace (63.52 % and 290.24 kcal/100g) whereas lowest (12.75 % and 12.75 kcal/100g) in fresh apple pomace. The increase in carbohydrate content and energy values might be due to the reduction in moisture content and an increase in the dry matter content of apple pomace. Similar results for carbohydrate content during drying of mango fruit pulp in different dryers [9]. The total soluble solid content, pH, titratable acidity and total solid content were recorded as 14.57°B, 3.06, 0.26 percent and 19.96 percent, respectively, in fresh pomace. Comparatively, higher values were recorded for TSS (28.12°B), pH (4.96), titratable acidity (1.13) and total solid content (91.77) per cent in dried apple pomace. The values of total soluble solid, pH, titrable acidity and total solid content were quite comparable with the results observed by [8], [36], [22]. The values of total sugar and reducing sugar was recorded as 25.29 percent and 12.73 percent in apple pomace after drying, whereas comparatively lower total sugar and reducing sugar content of 12.23 percent and 6.62 percent, respectively was recorded in fresh apple pomace. Similar values of total sugar and reducing sugar on fresh weight basis (8.15 % to 9.35 % and 4.09 % to 5.03 % respectively) and dry weight basis (21.07 % to 22.65 % and 15.12 % to 15.92 % respectively) were observed by [8], in pomace from three different apple varieties. Similarly, higher values of pectin and ascorbic acid was observed as 13.58 percent and 12.21 mg/100g in dried apple pomace powder, whereas the lower values of pectin (4.40%) and ascorbic acid (6.15 mg/100g) content were recorded in fresh apple pomace. Similar results were recorded by [8], [32].

The total phenol content (451.14 mg/100g) and antioxidant activity (85.37%) of apple pomace was observed higher after drying, as compared to fresh pomace as 95.26 mg/100g and 75.21 percent respectively. Similar results were recorded by [8]. This degradation may be reduced by pre-treatments before the dehydration process, such as the addition of chemical additives which inhibit or reduce the thermal degradation of polyphenols. Some studies have reported an increase in the antioxidant content derived from structural changes in tissues that may release bound antioxidant polyphenols [29], [30].

Table 1.3: Chemical characteristics of fresh apple pomace and dried apple pomace powder

Parameters	Mean ± SD		
	Fresh apple pomace	**Apple pomace powder**	**P-value**
Moisture content %	80.04 ± 0.05	8.23 ± 0.01	0.000
Ash content %	1.12 ± 0.01	2.06 ± 0.01	0.000
Crude fat %	0.63 ± 0.01	2.39 ± 0.02	0.000
Crude fibre %	4.65 ± 0.02	20.68 ± 0.01	0.000
Crude protein %	0.81 ± 0.01	3.12 ± 0.03	0.000

Carbohydrate %	12.75 ± 0.00	63.52 ± 0.00	0.000
Energy value (kcal/100g)	60.28 ± 0.50	290.24 ± 1.32	0.000
Total soluble solid (°B)	14.57 ± 0.04	28.12 ± 0.01	0.000
Titrable acidity (%)	0.26 ± 0.01	1.13 ± 0.03	0.000
Total solid (%)	19.96 ± 0.00	91.77 ± 0.00	0.000
Total sugar (%)	12.23 ± 0.05	25.29 ± 0.04	0.000
Reducing sugar (%)	6.62 ± 0.03	12.73 ± 0.02	0.000
Pectin content as calcium pectate (%)	4.40 ± 0.05	13.58 ± 0.23	0.000
Ascorbic acid (mg/100g)	6.15 ± 0.03	12.21 ± 0.07	0.000
Total phenol content (mg/100g)	95.26 ± 0.05	451.14 ± 0.25	0.000
Antioxidant activity (%)	75.21 ± 0.02	85.37 ± 0.15	0.000

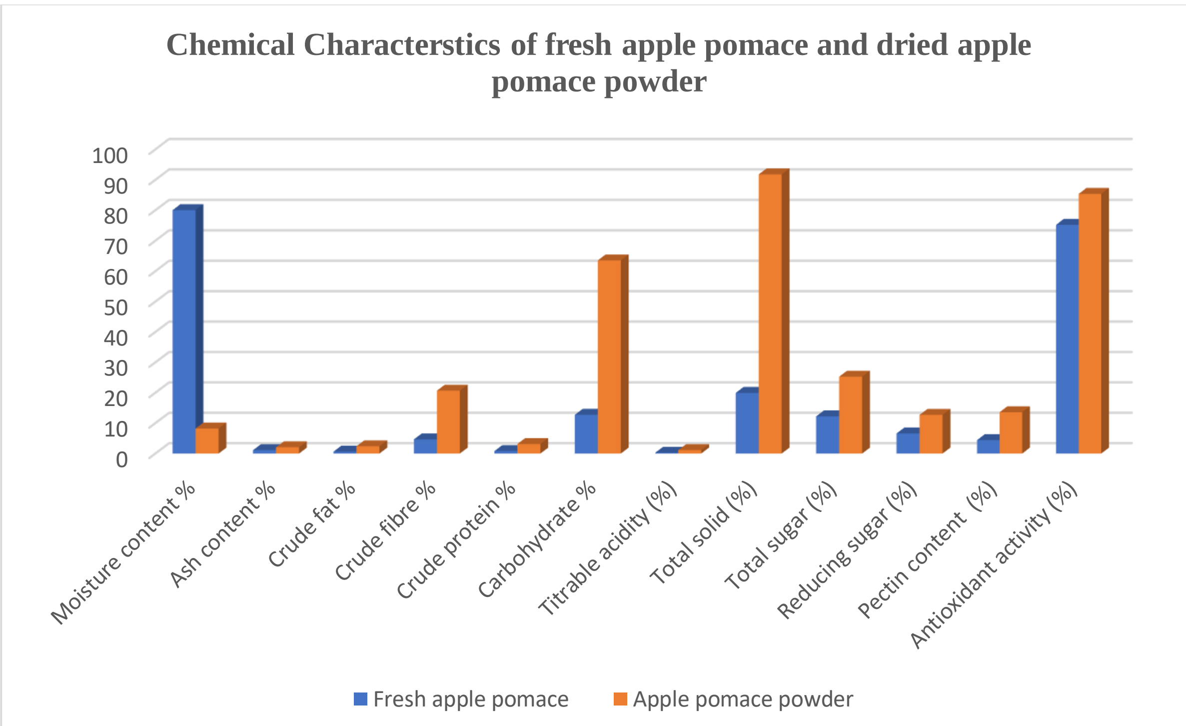

Figure 1.1. Effect of nutritional composition of fresh apple pomace and dried apple pomace powder

3.3 SPECTRAL ANALYSIS

The FTIR spectrum revealed carbohydrates, proteins, fats, alcohols, carboxylic acid and aromatic compounds, as shown in Table 1.4 and in Fig 1.2 with their respective peaks, area covered and the detected compounds. Fig 1.2 illustrates that the IR- spectra of organic matter, alcohol, fat, hemicellulose, lignin, Polysaccharides, pectin, Quinone (indication of color), carbon, amide (protein), amine, hydroxyl compounds, cellulose, ether, oxy compounds, aromatic compound, aryl thioethers, thiol or thiolether, disulfides, and alkyne compounds appeared as coupled stretching and bending as a pair of typical bands in the range of 900–4000 cm-1 at different peaks i.e., 3268, 2921, 2854, 1804, 1745, 1689, 1410, 1372, 1242, 1153, 1019, 870, 821, 776, 706, and 676 cm-1 for apple pomace powder.

Table 1.4 FTIR frequencies and their peak assignments for the spectra of apple pomace powder

Peak	Bond	Functional group

3268 cm^{-1}	C-H ring O-H stretching	Organic matter Alcohol
2921 cm^{-1}	C-H stretching	Lignin compounds
2854 cm^{-1}	CH_2 of lipids, Asymmetric CH_2 stretching mode of the methylene chain in membrane lipid	Fat
1804 cm^{-1}	C=O vibration of triglycerides	Hemicellulose, lignin
1745 cm^{-1}	Ester group C=O vibration of triglycerides C=O	Polysaccharides, pectin
1689 cm^{-1}	Cyclic organic compound containing two carbonyl groups C=O, either adjacent or separated by vinylene group	Quinone (indication of color)
1410 cm^{-1}	Phenol or tertiary alcohol, OH bend Carbon related compound	Carbon
1372 cm^{-1}	Aliphatic nitro compounds	Amide (protein)
1242 cm^{-1}	C-N stretching	Amine
1153 cm^{-1}	Tertiary alcohol, C-H stretch	Alcohol and hydroxyl compounds
1019 cm^{-1}	C-C vibrations	Cellulose
870 cm^{-1}	Peroxides, C-O-O- stretch	Ether and oxy zcompounds
821 cm^{-1}	C-H 1,4-Disubstitution (para)	Aromatic compound
776 cm^{-1}	C-S stretching, CH2-S-(C-S stretch)	Aryl thioethers, Thiol or thiolether
706 cm^{-1}	C-S stretch	Disulphides
676 cm^{-1}	Alkyne C-H bend	Alkyne, Spectral bands of cellulose, hemicellulose or pectin

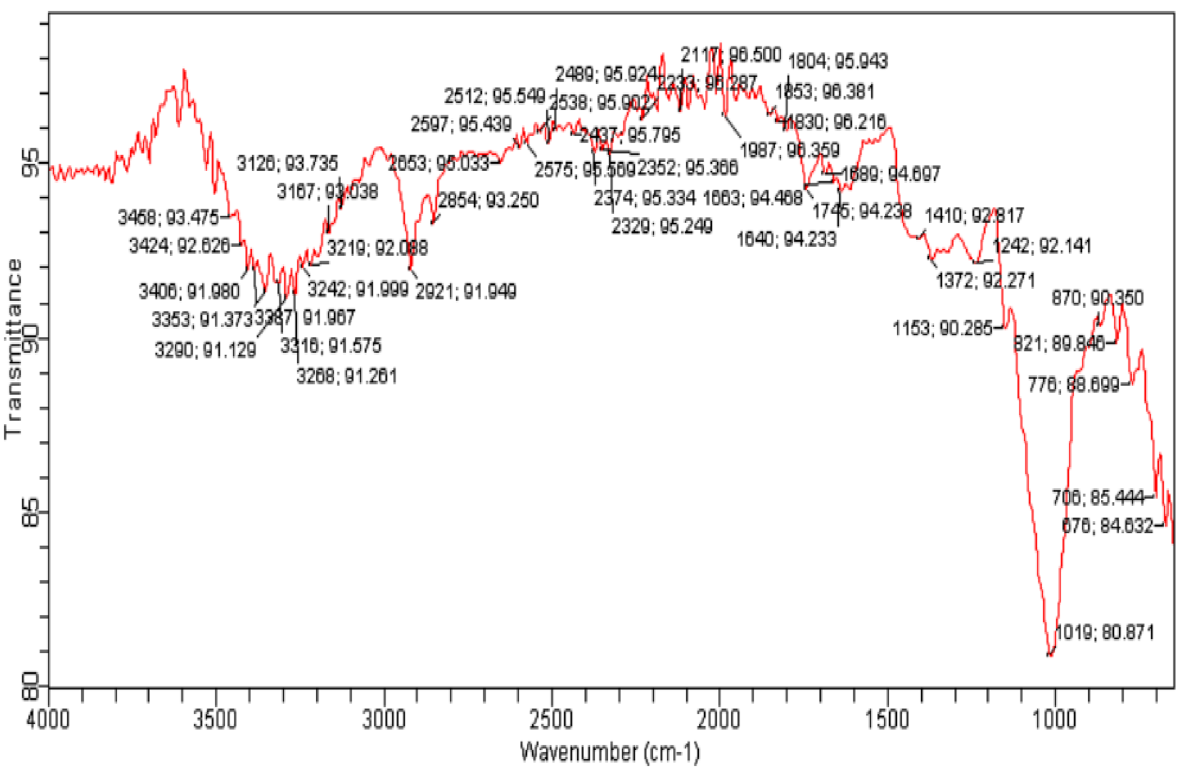

Figure 1.2. FTIR Spectra of apple pomace powder

4. Conclusion

Apple juice is amongst the most demanded apple products in the market, worldwide. During apple processing, only 75 per cent of the apple (fresh weight basis) is extracted for juice production and the remaining by-product i.e., pomace is generally discarded as waste. It is generally disposed of in landfills,

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which certainly leads to serious environmental hazards and pollution. Taking into consideration the large quantity of production of this by-product, the commercial usage of pomace can lead to a great economic impact.

This study highlighted the nutritional and functional composition of pomace (fresh and dried powder), which revealed that the fresh apple pomace is rich in numerous nutritional compounds such as carbohydrates, proteins, fats, phenols, total sugars, dietary fiber, organic compounds. However, the storage of pomace in its fresh form is quite challenging. Therefore, drying of pomace at 50 ± 2°C for 24 h, not only enhance the nutritional characteristics significantly but also increase the storage stability. The FTIR analysis reveal the presence of various organic acids, ethers, oxy compounds, alky compounds, phenols, quinones etc. focusing attention on its functional profile. There is still a need to study the risk factors regarding its consumption, however, it is relatively safe to eat and more applications need to be explored in order to its disposal methods in eco-friendly manner and to improve the quality and health aspects of numerous food products by using pomace as a valuable functional ingredient.

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