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ScienceDirect
Food Chemistry 104 (2007) 686–692
Food Chemistry
www.elsevier.com/locate/foodchem

# Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making

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Received 2 August 2006; received in revised form 20 November 2006; accepted 6 December 2006

**Abstract**

Apple pomace, a by-product of apple juice industry, is a rich source of fibre and polyphenols. Also in view of the antioxidant property of pomace, it would play an important role in prevention of diseases. Apple pomace procured from fruit juice industry, contained 10.8% moisture, 0.5% ash and 51.1% of dietary fibre. Finely ground apple pomace was incorporated in wheat flour at 5%, 10% and 15% levels and studied for rheological characteristics. 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. Resistance to extension values significantly increased from 336 to 742 BU whereas extensibility values decreased from 127 to 51 mm. Amylograph studies showed decrease in peak viscosity and cold paste viscosity from 950 to 730 BU and 1760 to 970 BU respectively. Cakes were prepared from blends of wheat flour containing 0–30% apple pomace. The volume of cakes decreased from 850 to 620 cc with increase in pomace content from 0% to 30%. Cakes prepared from 25% of apple pomace had a dietary fibre content of 14.2% The total phenol content in wheat flour and apple pomace was 1.19 and 7.16 mg/g respectively where as 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 fibre.


*Keywords:* Apple pomace; Farinograph; Extensograph; Pasting characteristics; Cake; Dietary fibre; Total phenol content

## 1. Introduction

Dietary fibre functions as a bulking agent and increases the intestinal mobility and moisture content of the feces (Forsythe, Chenoweth, & Bennink, 1976). Several authors have reviewed the importance of dietary fibre since 1970s (Eastwood, 1974; Leveille, 1975; Southgate, 1975). Dietary fibre consists of cellulose, hemicelluloses, lignins, pectins, gums etc. (Gallaher & Schneeman, 2001 & Lamghari et al., 2000). Dietary fibres from different sources have been used to replace wheat flour in the preparation of bakery products. Pomeranz, Shogren, Finney, and Bechtel (1977) used cellulose, wheat bran and oat bran in bread making. Potato peel, a by-product from potato industry, rich in dietary fibre, was used as a source of dietary fibre in bread making (Toma, Orr, D'Appolonia, Dintzis, & Tabekhia, 1979). Apple pomace is the residue that remains after the extraction of juice from apple. Dried apple pomace, a fruit industry by-product, is considered as a potential food ingredient having dietary fibre content of about 36.8% and has been used in apple pie filling and in oatmeal cookies (Carson, Collins, & Penfield, 1994). Apple fibre wheat flour blends were shown to have poor bread baking quality (Chen, Rubenthaler, & Schanus, 1988a). Further, Chen, Rubenthaler, Leung, and Baranowski (1988b) having characterized by chemical and physical methods, found apple fibre to be superior to wheat and oat bran. They used apple pomace in cookie and muffin formulations at 4% level so that the quality of the end product was acceptable. In addition, citrus and apple fibres are known to consist of bioac-

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0308-8146/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2006.12.016

tive compounds such as flavonoids, polyphenols and carotenoids and also have been considered as a source of better quality dietary fibre (Fernández-Ginéz, Fernández-López, Sayas-Barberá, & Pérez-Alvarez, 2003). Fernando, Maria, Ana Maria, Chiffelle, and Fernando (2005) evaluated for some functional properties and reported that fibre concentrates from apple pomace and citrus peel can be considered as a potential source for fibre enrichment. Masoodi, Bhavana, and Chauhan (2002) studied cake making from apple pomace wheat flour blends at 5%, 10% and 15%, so as to enrich the cake with fibre content. Fresh apples seem to have antioxidant activity equivalent to 1500 mg of vitamin C and are suppose to inhibit the growth of colon and liver cancer cells (Eberhardt, Lee, & Liu, 2000). Lu and Foo (2000) indicated that the polyphenols, which are mainly responsible for the antioxidant activity, are present in apple pomace and hence could be a cheap and readily available source of dietary antioxidants. Several workers have also carried studies on the recovery of pectin and phenolic compounds from apple pomace by several workers (Schieber et al., 2003; Escarpa & González, 1988; Jham, 1996; Lu & Foo, 1997; Schieber, Keller, & Carle, 2001). The objective of the present study was to characterize the apple fibre chemically, and to study its influence on dough properties and on cake making. Polyphenols present in the pomace as well as in cake prepared using apple pomace were also investigated.

## 2. Materials and methods

### 2.1. Materials

Dried apple pomace was procured from a fruit juice industry (Southern Citrus Products Pvt. Ltd., Gudur, India). The dried apple pomace consisting of peel, stem and seed along with residue of juice extract was ground to powder to pass through 150 μm sieve. Commercial wheat flour procured from local market, having 11.4% moisture, 10.1% protein and 0.45% ash was used in the study.

### 2.2. Chemical analysis

Dried apple pomace was analysed for moisture, ash, protein and fat contents as per the standard AACC methods (2000). Nitrogen content was estimated by semi-micro Kjeldhal method and was converted to protein using factor 6.25. Total dietary fibre (TDF), soluble (SDF) and insoluble (IDF) dietary fibre contents were estimated according to Asp, Johansson, Hallmer, and Siljestroem (1983). Bulk density of the apple pomace was determined using a calibrated graduated cylinder. Cylinder was filled with apple pomace with slight shaking and the contents of the cylinder was weighed and expressed as g/ml. The packed density was determined by pressing the sample in a graduated cylinder using a rubber stopper attached to a glass rod (Chen et al., 1988b). For water holding capacity determination, 1 g of apple pomace powder was mixed with 50 ml of distilled water vigorously for 1 min and then centrifuged for 15 min at 10,000*g* at 20 °C. The supernatant was discarded and the tube was kept inverted for 10 min. Moisture content of the precipitate was determined (Chen et al., 1988b). All analysis for the samples were carried out in triplicate and average value was expressed.

### 2.3. Rheological characteristics

Apple pomace blends at 0%, 5%, 10% and 15% levels were prepared by replacing wheat flour. The effect of apple pomace on the mixing profile of the dough was studied using farinograph (Brabender, Duisburg, Germany) according to the standard AACC methods (2000). The elastic properties of the dough was studied using extensograph (Brabender, Duisburg, Germany) according to the standard AACC methods (2000). Pasting characteristics of the blends were determined using visco-amylograph (Brabender, Duisburg, Germany) according to the standard AACC methods (2000).

### 2.4. Baking tests

Cakes were prepared from blends containing 0%, 10%, 20% and 30% of apple pomace. The formula included 100 g flour blend, 100 g sugar, 120 g egg, 25 g shortening, 40 g refined vegetable oil, 0.5 g baking powder and 1.5 g salt. Cake batter was prepared in a Hobart mixer (N-50) using flour batter method, wherein, the flour, shortening, salt and baking powder were creamed together to get a fluffy cream; eggs and sugar were whipped together until semi-firm foam resulted. The sugar–egg foam was mixed with the creamed flour and shortening, after which the vegetable oil was added in small portions. Cake batter (450 g) was poured into a wooden pan and baked at 160 °C for 1 h. Cakes were cooled to room temperature and packed in polypropylene pouches.

### 2.5. Physical characteristics of cakes

Volume (V, cc) of cakes was measured using rapeseed displacement method. Weight of the cakes was measured (W, g) and density (W/V, g/cc) was calculated. The texture of the cakes was measured objectively using food texturometer (TAHDi, Stable Micro System, UK) as per the standard AACC methods (2000). A pre-test speed of 2.0 mm $s^{-1}$ and a test speed of 1.67 mm $s^{-1}$ were used. A 35 mm diameter cylinder aluminum probe (P-35), was used to measure the required compression force. Force required to compress 25% of the cake slice (2.54 cm) was recorded.

### 2.6. Sensory analysis

Sensory evaluation of cakes were carried out by six panelists on a five point hedonic scale for different parameters such as crust colour, crumb colour, grain, texture, eating quality and overall quality.

### 2.7. Statistical analysis

The sensory evaluation data was statistically analysed and the treatments were tested using Duncan's multiple range test (Steel & Torrie, 1980).

### 2.8. Determination of total phenol content

Raw materials namely wheat flour and apple pomace and cakes prepared from 0% and 25% apple pomace blends were analysed for total phenol content. one g of defatted sample {after refluxing with chloroform and petroleum ether, (1:1 v/v) followed by drying} was mixed with 10 mL of water for aqueous extraction. Similarly for methanol extraction, 1 g of defatted sample was mixed with 10 mL of methanol, stirred and centrifuged at 2000*g* for 15 min. The above supernatants were referred as water extract (WE) and methanol extract (ME), respectively. Extracts were stored at 4 °C till the completion of the experiment. The total phenolic contents of the WE and ME were determined colorimetrically using the Folin–Ciocalteau method (Singleton, Orthofer, & Lamuela-Raventos, 1999). Sample aliquot of 20–100 μL were added to 900 μL water, along with 1 mL of Folin–Ciocalteau reagent and 2 mL of 10% sodium carbonate solution were together mixed in a cyclo mixer and incubated for 1 h at room temperature. The absorbance was measured at 765 nm with a Shimadzu UV–Visible Spectrophotometer (Shimadzu, Germany). The total phenolic content was expressed as milligram gallic acid equivalent (GAE) per gram sample.

## 3. Results and discussion

### 3.1. Chemical characteristics of apple pomace

The results of chemical analysis of apple pomace is presented in Table 1. Apple pomace had moisture and protein contents of 10.8 % and 2.06 % respectively. The total dietary fibre content (TDF) was 51.1%, which is about 15–17% higher than the values reported by Carson et al. (1994). Chen et al. (1988b), in their studies have reported TDF of about 61.9% in apple fibre. The soluble fibre (SDF) was found to be 14.6% where as the insoluble fibre (IDF) was 36.5%. The bulk density of the apple pomace was 0.52 g/cc and packed density was 0.71 g/cc. The water holding capacity for wheat flour and apple pomace was 1.01 and 8.39 g water/g solid, respectively, indicating that the fibre had higher water holding capacity. These results are comparable to that reported by Chen et al. (1988b).

Table 1
Proximate composition of apple pomace

| Parameters | (%) |
|---|---|
| Moisture | 10.80 ± 0.03 |
| Total ash* | 0.50 ± 0.05 |
| Total fat* | 2.70 ± 0.10 |
| Total protein* | 2.06 ± 0.05 |
| Total dietary fibre** | 51.10 ± 1.86 |
| Insoluble fibre** | 36.50 ± 1.14 |
| Soluble fibre** | 14.60 ± 0.14 |
| Bulk density (g/cc) | 0.52 ± 0.06 |
| Packed density (g/cc) | 0.71 ± 0.03 |
| WHC (g $H_2O$/g solid) | 8.39 ± 0.05 |

WHC – water holding capacity.
* On 14% moisture basis, values are means ± standard deviations ($n = 3$).
** On dry basis, values are means ± standard deviations ($n = 3$).

### 3.2. Farinograph characteristics of wheat flour-apple pomace blends

The results of the dough properties as affected by apple pomace are shown in Fig. 1. Increase in apple pomace content in the blend from 0% to 15%, increased the water absorption from 60.1% to 70.6%. Chen et al. (1988a) also reported an increase in water absorption of about 71.2–88.7% with incorporation of apple fibre from 0% to 12%. Dough development time increased from 1.5 to 3.5 min and dough stability decreased from 4.2 to 2.1 min. An increase in the dough development time indicates that an increase in fibre content in the blends has slowed the rate of hydration and development of gluten. Mixing tolerance values increased from 32 to 100 BU, which is due to dilution of gluten protein with the fibre content. This may also be due to the interaction between fibrous materials and gluten, which affects the dough mixing properties as reported by Chen et al. (1988a).

### 3.3. Extensograph characteristics of wheat flour-apple pomace blends

Effect of apple pomace on the elastic properties are illustrated in Fig. 2. With increase in apple pomace content to 30%, the resistance to extension value increased from 336 to 742 BU and extensibility values decreased from 127 to 51 mm. This may be either due to the dilution of gluten proteins or interactions between polysaccharides and proteins from wheat flour as reported by Chen et al. (1988a). The ratio figure values drastically increased from 2.6 to 14.5 with increase in apple pomace content to 30% in the blend. The data indicates that the dough became stiff with increase in apple pomace in the blend.

### 3.4. Pasting characteristics of wheat flour-apple pomace blends

Pasting temperature (PT), which is the first deflection of temperature in amylogram, where the curve begins to rise (Rasper, 1980) increased from 60 to 63 °C with increase in apple pomace content from 0% to 15%. The difference in pasting temperature may be due to the effect of varying gelation temperatures of the fibre fractions (Naruenartwongsakul, Chinnan, Bhumiratana, & Yoovidhya, 2004). Peak viscosity decreased from 950 to 730 BU (Fig. 3.) with increase in the apple pomace in the blends indicating that the swelling power, which is the ability of

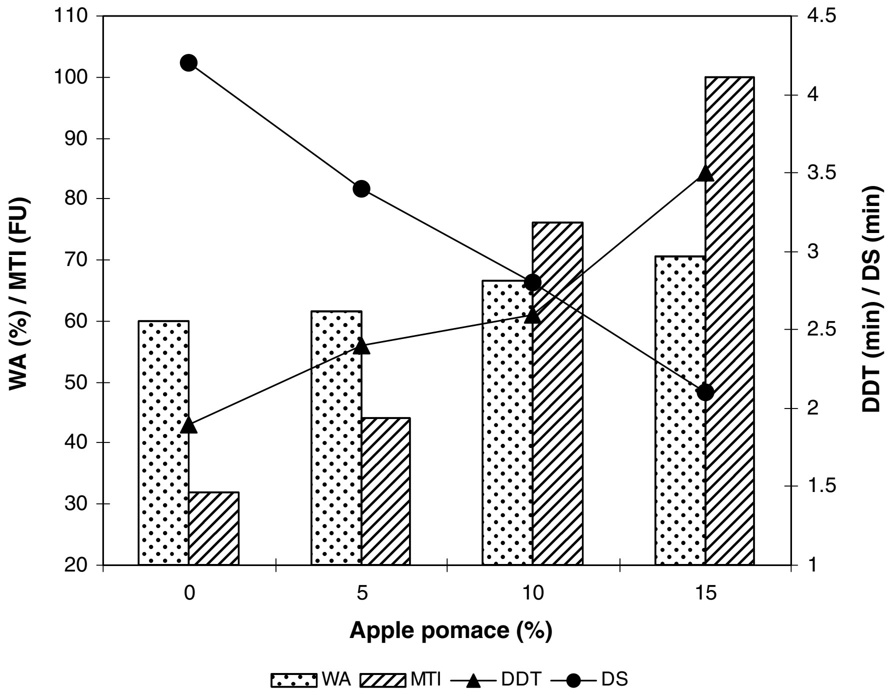


Fig. 1. Effect of apple pomace on the farinograph characteristics. WA: water absorption (%), MTI: mixing tolerance index (FU), DDT: dough development time (min) and DS: dough stability (min).

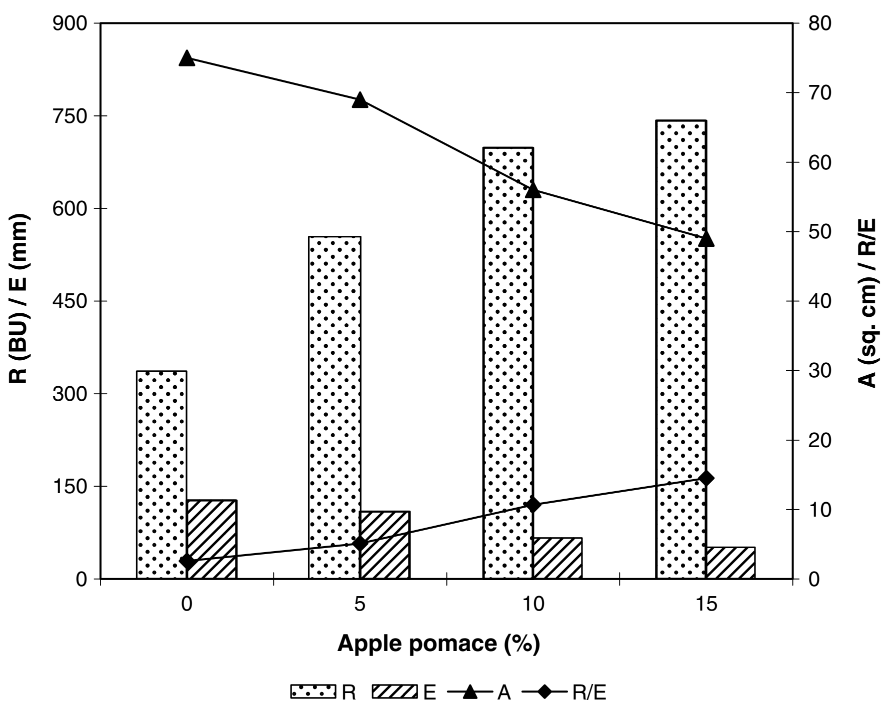


Fig. 2. Effect of apple pomace on the extensograph characteristics. *R*: resistance to extension (BU), *E*: extensibility (mm), *A*: area ($cm^2$) and *R*/*E*: ratio figure.

the starch granules to swell freely before their break down decreased (Tipples et al., 1980). Hot paste viscosity (*H*) attained at 95 °C, after 20 min of holding period decreased from 760 to 490 BU. The breakdown values ($P-H=$ BD; difference of maximum viscosity and viscosity at 95 °C), which is related to the starch, increased from 90 to 240 BU with increase in the pomace content. The higher BD values at higher concentration of pomace content indicate that the fibre fraction interacted with the starch and make the swollen granules more fragile. Similar results are

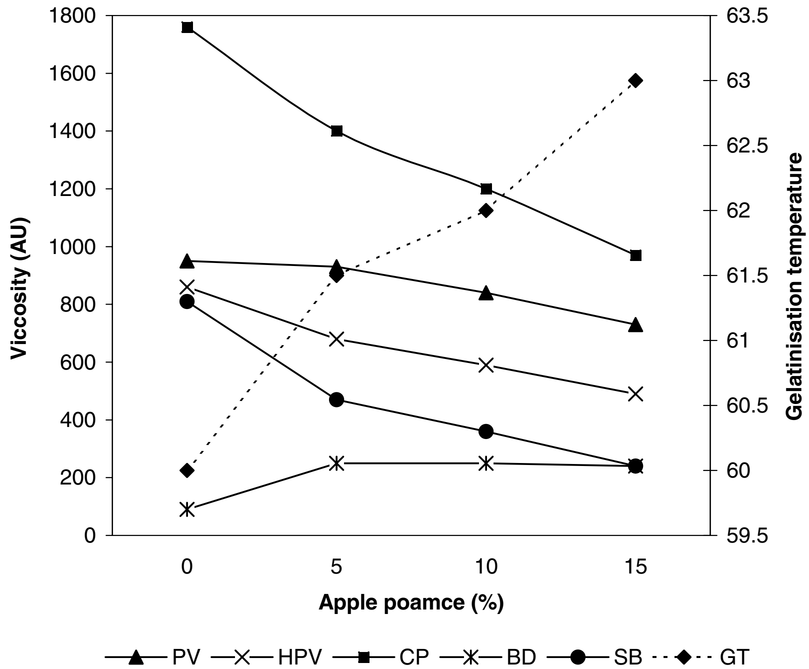


Fig. 3. Pasting characteristics of wheat flour–apple pomace blends. PV: Peak viscosity (BU), HPV: hot paste viscosity (BU), CP: cold paste viscosity (BU), BD: break down viscosity (BU), SB: set back viscosity (BU), GT: gelatinisation temperature (°C).

reported by Rojas, Rosell, and Benedito (1999), where some of the hydrocolloids increased the BD values. Cold paste viscosity decreased from 1760 to 970 BU and set back values drastically decreased from 810 to 240 BU.

### 3.5. Baking characteristics

Cakes were prepared by replacing wheat flour at 10%, 20% and 30% levels of apple pomace and the physical properties of cake are presented in Table 2. As the concentration of apple pomace increased from 0% to 30%, the volume of the cake decreased from 850 cc to 620 cc and the density of the cakes increased from 0.48 to 0.67 g/cc, which is also reflected in the texture measurement values. Chen et al. (1988b) reported that the density of the cakes increased due to the strong water binding properties of apple fibre. The texture of the cakes measured objectively using food texturometer, showed that the cakes became harder with increasing levels of apple pomace (1.03–1.46 g). Sensory evaluation (Table 3) of the cakes showed that the scores for crust decreased only at 30% level of addition of apple pomace. The scores for crumb colour decreased significantly as it changed from creamish yellow to brown colour. Crumb grain scores reduced as the cakes had more compact cells and were dense. This is also reflected in the density values of the cakes presented in Table 2, which increased from 0.48 to 0.67 g/cc. However, with increasing levels of apple pomace, cakes had pleasant fruit flavour. Though the over all quality scores reduced, the cakes prepared from 20% apple pomace was highly acceptable.

### 3.6. Nutritional facts of cakes

Cakes prepared using 0% and 25% of apple pomace in the blend and were analysed for different parameters. Table 4 shows that the moisture content, total fat content and protein values ranged between 20.9–21.8%, 19.3–20.5% and 8.5–8.46% respectively. This shows that both the cakes had similar moisture, fat and protein contents. Total dietary fibre content (TDF), on the other hand, for cake containing apple pomace was as high as 14.2% while it was 0.47% for control cake. Similarly soluble dietary fiber (SDF) was 0.16 and 5.8% for cakes prepared from 0%

Table 2
Effect of apple pomace on the physical quality of cakes

| Apple pomace (%) | Volume[a] (cc) | Weight[a] (g) | Density (g/cc) | Texture[*,b] (kg force) |
|---|---|---|---|---|
| 0 | 850 ± 11.18 | 419.3 ± 10.08 | 0.48 | 1.03 ± 0.18 |
| 10 | 830 ± 10.21 | 406.2 ± 9.12 | 0.49 | 1.15 ± 0.22 |
| 20 | 775 ± 9.80 | 408.7 ± 8.13 | 0.53 | 1.23 ± 0.59 |
| 30 | 620 ± 9.15 | 413.0 ± 7.23 | 0.67 | 1.46 ± 0.12 |

Values are means ± standard deviations (a: $n = 4$, b: $n = 8$).
[*] Objective measurement.

Table 3
Effect of apple pomace on the sensory quality of cakes

| Apple pomace (%) | Crust colour (5) | Crumb characteristics | | | | |
|---|---|---|---|---|---|---|
| | | Colour (5) | Grain (5) | Texture (5) | Eating quality (5) | Overall quality (5) |
| 0 | 4.5a | 4.5a | 4.5a | 4.5a | 4.5a | 4.5a |
| 10 | 4.0ab | 4.0ab | 4.5a | 4.5a | 4.0a | 4.0a |
| 20 | 4.0ab | 3.5b | 4.0a | 4.0a | 4.0a | 4.0a |
| 30 | 3.5b | 3.0c | 3.0b | 3.0b | 3.0b | 3.0b |
| SEM (±) | 0.23 | 0.09 | 0.11 | 0.26 | 0.10 | 0.18 |

Values for a particular column followed by different letters differ significantly ($p < 0.05$); SEM: Standard error of mean at 20 degrees of freedom.

Table 4
Nutritional facts of cakes

| Nutritional parameters | Blend (0%) | Blend (25%) |
|---|---|---|
| Moisture (%) | 20.9 ± 0.16 | 21.8 ± 0.14 |
| Total fat* (%) | 19.3 ± 0.14 | 20.5 ± 0.19 |
| Crude protein* (%) | 8.5 ± 0.03 | 8.46 ± 0.04 |
| Total dietary fibre* (%) | 0.47 ± 0.14 | 14.20 ± 1.04 |
| Insoluble fibre* (%) | 0.31 ± 0.02 | 8.40 ± 0.79 |
| Soluble fibre* (%) | 0.16 ± 0.06 | 5.80 ± 0.68 |

* On dry basis, values are means ± standard deviations ($n = 3$).

and 25% apple pomace blend, respectively. This clearly indicates that apple pomace can be an alternative source of dietary fibre in cake making.

### *3.7. Total phenol content*

The total phenol content for different samples is illustrated in Table 5. The data shows that the phenol content in apple pomace (10.16 mg/g) is six times higher than that present in wheat flour (1.19 mg/g), indicating that the apple pomace is rich in both water and methanol soluble phenols. Cake prepared from wheat flour only (0% apple pomace) had 1.31 and 0.76 mg/g of WE and ME phenols respectively, where as cake prepared from 25% apple pomace blend had 1.87 and 1.28 mg/g of WE and ME phenolic contents respectively, showing a 50% increase in polyphenol content. However, baking or drying at temperature above 60 °C is regarded as unfavourable due to the possibility of inducing oxidative condensation or decomposition of thermo-liable compounds like phenolics (Asami, Hong, Barrett, & Mitchell, 2003). The higher amount of phenolic content in the latter cake can also be due to components derived from apple pomace and the formation of intermediates such as enediols and reductoines during baking process, which interferes with the colorimetric assay (Van Buren, De Vos, & Pilnik, 1976).

Table 5
Total phenol content

| Sample | Water extract (mg/g) | Methanol extract (mg/g) | Total phenol content (mg/g) |
|---|---|---|---|
| Wheat flour | 0.78 | 0.41 | 1.19 |
| Apple pomace | 4.65 | 5.51 | 10.16 |
| Cake (0% blend) | 1.31 | 0.76 | 2.07 |
| Cake (25% blend) | 1.87 | 1.28 | 3.15 |

## 4. Conclusion

Apple pomace like any other fibre source increases the water absorption capacity of the flour. In general apple pomace affected the elastic properties of the wheat flour dough as well as the pasting properties. Apple pomace having high amount of TDF can function as a valuable source of dietary fibre in cake making. Cakes prepared from 25% of apple pomace-wheat flour blend had 14.2% TDF with high acceptable quality. Addition of apple pomace in cake making can avoid the addition of other flavouring ingredients as the cakes prepared with apple pomace had pleasant fruity flavour. Apple pomace also has the potential for use in cake making as a good source of polyphenols which has antioxidant properties.

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