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Enhanced functional properties and shelf stability of muffins by fortification of kinnow derived phytochemicals and residues

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Abstract

The study was conducted to utilize kinnow waste (peel and pomace) and peel derived phytochemicals in the fortification of muffins to improve functional properties and shelf stability. The dried kinnow peel and pomace powder were utilized in the muffinfortification by replacing wheat flour in various levels viz., 5, 10, 15 and 20%, to ensure enhanced quality and acceptability. The peel (Mp) and pomace (Mpo)supplemented muffins showed higher crude fiber (3.57±0.10%- and 2.82±0.30%) and ash (1.55±0.09%-peel and 1.33±0.01% for pomace) as compared to the control (Butylatedhydroxyanisole).Also, the functional properties like phenolics, flavonoids and antioxidants were enhanced in the muffins prepared with waste.Phytochemicals were added as 1, 2, 3 and 4%. The concentration level of 4% of phytochemicals resulted in the higher phenolics (12.34±0.07 mg/g of Gallic acid equivalent), flavonoids (0.50±0.09mg/g of quercetin equivalent), carotenoids (0.82±0.01 mg/100g) and antioxidant activities (2,2-diphenyl-1-picrylhydrazyl DPPH(59.71±0.08%) and ferric reducing antioxidant power(FRAP) 23.46±0.18mM/g) as compared to the other muffins. In the shelf life stability, muffins fortified with 10%peel (Mp)and 4 % of phytochemicals (Mph) provided better stability as compared to control (with Butylatedhydroxyanisole)and 5% of pomace. Theyalso possessed higher oxidative stability than the control. Thus it can be concluded that kinnow waste can be utilized as an ingredient for making the foods with high functional value.

***Keywords**: Muffins, Phytochemicals, peel, pomace, antioxidants, stability*

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1. INTRODUCTION

Kinnow mandarin (*Citrus reticulate* L.) is a hybrid of King and Willow leaf and belongs to the citrus family (Sharma et al., 2007). In India, J. C. Bakhshipresented this variety in 1954 at the Punjab Agricultural University, Regional Fruit Research Station, Abohar (Qadir 2018). The post-harvest losses in kinnow are around 21.91% in India andhuge quantity of peels are also generated as by-product during the processing of citrus fruits which do not add value to the product as these are discarded or dumped and account for about 50 per cent of the total fresh fruit weight (Babbaret al. 2011). Kinnow peel, pulp and seeds are obtained as a major processing waste.

The wastes from citrus industry contain high organic matters and moisture contents (around 82 per cent on wet basis), which turns them into toxic and hazardous environment pollutants (Perazziniet al. 2010). In addition, the cost of drying and storage or transportation concern with financial limitation for waste utilization. All such factors and nonexistence of a proper management and non-availability of any technology, these wastes are either disposed off for decomposition and compost production or burnt (Ajilaet al. 2010). This has led to a drive by the agro industries, for waste reduction and upgrading techniques to achieve new sources of income and to the reduce costs. In fact, agro waste may be a source of high value- added products potentially useful as beneficial food constituents, food flavors and antioxidants or as cosmetics, chemo preventive agents, drugs or drug adjuvants. These wastes consisting of worthwhile nutrients represent valuable biomass (Daret al. 2019). Flavonoids, carotenoids, lemonoids and ascorbic acids are the important phytochemicals which provide it with this potential. Citrus peels are the richest sources of bioflavonoids, with comparatively higher polyphenol content compared to the pulp (Safdaret al. 2017). In citrus fruits, about three-fourth of the vitamin C is present in the peel, pulp and seed, that goes waste (Nagy 1980, Mann et al. 2013). There is a growing acceptance that amino acids,

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phenols, pectin, essential oils, flavonoids, carotenoids and vitamin C present in citrus fruits exert beneficial effects in the prevention of degenerative diseases (Wanget al. 2014).

The consumption of bioactive compounds present in the food is now considered as significant as vitamins for health promotion and defense against damage caused due to oxidative stress. There is an indication that extracts from fruits with high polyphenol content and vitamin C are effective in decreasing the concentration of intracellular reactive oxygen species (ROS) and in protecting DNA, lipid and mitochondrial functionality from the injuryprompted by free radicals (Giampieri et al. 2014). In this context and framework,it becomes imperative to emphasize on the kinnow fruit being double fortificant of fiber, ash, and antioxidants, as natural and cheap source, having protective properties (Friedman &Jurgens 2000) and shown to lower oxidative stress-related diseases and ageing.

Bakery items are eaten widely and becoming a chiefconstituent of the international food market (Kotsianiset al. 2002). Muffins areamong the most common bakery foods consumed by people in the world. Nowadays, lipid oxidation is the major problem faced by cake manufacturer's which limits the shelf life of their products. These are basically high lipid foods which tend to become rancid after prolonged storage owing to the oxidation of polyunsaturated fatty acids (Ray & Husain 2002,Izzreen&Noriham 2011).Distinctive attention has been given to the use of antioxidant because of the world-wide inclinationtowards the use of synthetic food additives. In the recent years also, an upward trend in bakery products with increased nutritional value, such as fibre-enriched and natural antioxidants suggests that products, has been a good impact on the consumers (Al-Sayedand Ahmed 2013). Keeping in view the above mentioned facts, the present study was designed to utilize kinnow waste (peel, pomace and phytochemicals from the peel) in the bakery products and to evaluate a comparison based study between the artificial antioxidants and natural ones along with the study of their shelf life.

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2. MATERIAL AND METHODS

2.1 Procurement of material and sample preparation

Ripe kinnow fruits were procured from the Regional Research Centre Abohar Punjab (Punjab Agricultural University (PAU) Ludhiana) and were taken to the Food Industry Business Incubation Centre, in the Department of Food Science and Technology, Punjab Agricultural University. The Fruits were washed with tap water to remove dust, dirt, micro-flora and pesticide contaminations. Other materials like Flour, Shortening, Sugar, Salt, Leavening agent, Eggs, Emulsifierand packaging material were procured from the local market**.** Kinnow peel and pomace was obtained after the juice extraction. The peel and the pomace were dried in the oven at 45^{0}C for 48 hours. Both the samples were milled in a mixer/ blender, packed and stored at cold place.

2.2 Extraction of phytochemicals

Speed Super critical fluid extraction (model 7071 instrument Applied Separations, Allentown PA, USA), fitted with a pressure unit (Model 7071) along with a thick-walled stainless steel cylinder-shaped extractor vessel was employed for the extraction of phytochemicals. Chiller was used for the cooling of Carbon dioxide before pumping and pressurizing into the system along with the co-solvent. Phytochemicals from kinnow peel powder were extracted using the method of Toledo-Guillén et al. 2010. Sample of 20 g was packed in the extractor with ethanol as co-solvent (23%), critical pressure of 400 bars and a critical temperature of 333K respectively. The ethanol was then evaporated in a vacuum evaporator(Equitron-EV11.ABB.053). The peel phytochemical extract (SFE) obtained was stored under refrigeration until further use. The evaporated residue were re-dissolved at a concentration of 1 mg/mL in their particular solvent as used for their extraction and stored at 4^{0}C until analyzed for their functional components. The flow rate of the CO_2 at the exit of the system was controlled and kept constant at 3 L/min during the experiments.

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2.3 Physico-chemical parameters

The dried samples as well as the muffins were evaluated for physico-chemical parameters as per standard procedures. Moisture, ash, fat and proteins were estimated as per the standard AACC (2000) methods. Kjeldhal method was used for the estimation of nitrogen of the samples and was converted to protein using factor 6.25. The fibre content was determined using Fibertec (Foss instrument, Sweden) using AOAC (2016) procedure. The carbohydrate percent was calculated by subtracting percent moisture, proteins, fats and ash from 100.

2.4 Phytochemical analysis

For the determination of phytochemicals and antioxidants from the muffins, the samples were extracted with 80% methanol for 3 hours using refluxing method (Dhananiet al. 2013)

Total phenolic content of the samples were determined by using FolinCiocalteau (FC) method as described by Singltonet al. (1999). The Total Flavonoids were estimated by Aluminum chloride assay (Zhishenet al.1999). Total carotenoids and ascorbic acid were evaluated by Ranganna (2001) along with β-carotene (Guimaraeset al.2010).

2.5 Antioxidant activity

Two types of antioxidant assays were used to evaluate the free radical scavenging activity of the extracts like DPPH (1, 1-diphenyl-2-picryl-hydrazyl) and FRAP (Ferric reducing antioxidant power).

2.5.1 DPPH

The free radical scavenging activities of samples were determined against free radicals as described by Yi et al. (2008) with some modifications. Briefly an aliquot of 1ml of sample solution was mixed with 3ml of methanolic solution of DPPH (0.2mM) and then incubated in dark for 30 minutes. The absorbance was measured at 517nm. For control similar procedure was followed, but instead of sample, respective absolute solvents were used. The scavenging ability was calculated as;

$$\% \text{ Inhibition of DPPH radical} = \text{Ac} - \text{As}/\text{Ac} * 100$$

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Where

$$Ac = \text{Absorbance of control and}$$

$$As = \text{Absorbance of sample}$$

2.5.2 FRAP

The ability of the phytochemicals to reduce $FeCl_3$ solution was performed according toStratilet al. (2006) with some modifications. Briefly in 0.5ml of the extract, 1.8ml of the FRAP solution containing freshly prepared Acetate buffer (300Mm, Ph-3.6), TPTZ (10Mm dissolve in 40mM HCl) and $FeCl_3$ (20mM) dissolved in the ratio of 10:1:1; was added. Then it was conditioned at 37^0C for 15 minutes and the absorbance was recorded at 593nm. Fresh $FeSO_4$ solution was prepared and used for calibration. The antioxidant capacity was calculated from the linear equation plotting the standard curve as;

$$y = 0.0234x - 0.015; \qquad r^2 = 0.998$$

$$\text{Where } y = \text{absorbance and } x = \text{concentration}$$

2.6 Preparation of muffin

The ingredients used for the preparation of muffins are given in the table 1. Fat and sugar were whipped in Hobart mixer at high speed until creamy; egg and essence added and whipped again till the formation of good emulsion. Dried ingredients (flour, salt and baking powder) were sieved and added to the emulsion in parts**,** water was added and the batter was mixed slowly to desired consistency. The batter was then poured in greased muffin moulds and baked at 180°C for 20 min.

For the addition of powdered peel and pomace, flour was replaced as 5, 10, 15, and 20% respectively and the phytochemicals extracted by SFE were also added at the levels of 1, 2, 3and 4% respectively. One control sample (muffins) containing artificial antioxidant (BHA-0.02%) was also prepared. The control sample was used to compare its oxidative stability with the fortified muffins

Table 1. Formulation used for the preparation of muffins

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2.7 Physical characteristics of Muffins

Volume of the muffins was measured using rapeseed displacement method.Weight of the muffins was calculated and then specific volume was measured by the following formula.

$$\text{Specific volume } \left(\frac{\text{cc}}{\text{g}}\right) = \frac{\text{volume of muffin (cc)}}{\text{weight of muffin (g)}}$$

2.8 Free fatty acids

Standard AACC (2000) procedure was followed with some modifications. For the extraction of free fatty acids 8 g of sample was added with 50 ml benzene and allowed tostand for 30 min. To 5 ml of thisextract 5 ml benzene and 10 ml of ethanol was added and titrated against 0.02N KOH using phenolphthalein as an indicator until light pink colour appeared. The free fatty acids were calculated using following formula

$$\text{FFA (\% oleic acid)} = \frac{282 \times \text{normality of KOH} \times \text{volume of KOH used}}{1000 \times \text{weight of sample}} \times \text{dilution factor} \times 100$$

2.9 Peroxide value (PV)

PV was determined according to the methods of AOAC (2016). To5 g of sample, 50 ml of chloroform was added and shaked for 2-3 h. Contents were filtered through Whatman No.1 filter paper.To 20 ml aliquot 30 ml glacial acetic acid was added followed by addition of 1-2 ml of saturated potassium iodide solution. After 2-3 min, the mixture was diluted with 50 ml distilled water, added with2 ml of 1 percent starch solution and titrated against 0.01N $Na_2S_2O_3$ till colorless. Peroxide value was calculated using following formula

$$\text{Peroxide value } \left(\text{meq} \frac{\text{O2}}{\text{kg}} \text{ of fat}\right) = \frac{(\text{sample} - \text{blank}) \times \text{normality of Na2S2O3} \times 1000}{\text{weight of sample (g)}}$$

2.10 Color analyses

The colour of the muffins was measured by Minolta colorimeter CR-300 (Konica Minolta, Osaka, Japan). Results were expressed as L, a* and b* values according to the hunter colour lab system (Kimura et al.1993).

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2.11 Sensory evaluation

Muffins were evaluated by six semi-trained panellist from theDepartment of Food Technology (PAU) for color, texture, flavor and overall acceptability using 9- point hedonic scale as per the proforma (Poste et al. 1991).

2.12 Statistical analyses

The data was analysed for analysis of variance (ANOVA) using SAS 9.4. The means were compared using Ducan'sMultiple Range Test (DMRT).

3. Results and discussions

3.1 Proximate composition

The proximate composition of wheat flour, peel, pomace and phytochemical extracts is given in the Table 2. The data showed a protein content of 10.72±0.36 percent which was significantly higher than the protein content of peel and pomace. Fiber and ash content was significantly higher in peel and pomace than the flour. This was also reported by Ojha&Thapa (2017) in mandarin peel. SFE contained non-significant levels of protein, carbohydrates, fat and crude fiber.

Table 2: Proximate composition of wheat flour, peel powder, pomace powder and phytochemical extracts

3.2Supplementation of muffins with peel and pomace

Variation in the concentrations of peel and pomace for the preparation of muffins were assessed by replacing the wheat flour and the sensory scores were assigned by the panel of judges (Table 3 and 4) for their acceptance. The final concentration was selected and evaluated further for the physio-chemical, phytochemical parameters and storage stability. The results showed that there was not any significant difference ($p<0.05$) between the control and the muffins with 5% of pomace. Muffins fortified with peel (0, 5 and 10 percent level) were also non-significant at $p<0.05$. Colour values in peel were non-significant ($p<0.05$) on increasing the levels. Concentration levels of 10 Percent peel and 5 percent pomace were found acceptable by panel of judges. Higher levels were bitter due to limonoids, a bitter component

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present more in pomace as compared to peel (Premiet al. 1994). Zakeret al. (2017) reported 10 percent of orange peel powder having higher acceptability for the preparation of cake. Gil-Man Shin (2015) also supported the above statement.Sharobaet al. (2013) reported 5 percent and 10 percent of orange waste best for cake making by replacement of wheat flour. This indicates that the peel and pomace can be used or added in the cakes and thus reducing the waste

Table 3: Effect of supplementation of dried peel powder of kinnow on the sensory parameters of muffins

Table 4: Effect of supplementation of dried pomace powder of kinnow on the sensory parameters of muffins

3.3Supplementation of muffins with phytochemicals

The extracted phytochemicals utilized for the fortification of muffins at varied concentrations (1%, 2%, 3% and 4%) revealed that 4 percent level of concentration was observed to be more acceptable (Table 5). Levels of 1, 2 and 3 percent were non-significant ($p<0.05$) with respect to the control. So this level (4%) was further finalized for their evaluation of physico and phytochemical parameters. The flavor/ taste of the lower levels were same as that of control however 4 percent level gave a characteristic orange flavor. Reddy et al. (2005) used some plant extracts for the evaluation of antioxidants in biscuits, they found a threshold level of 2 percent was best than the other levels of extracts. Trabelsiet al. (2013) added essential oil extracted from *Citrus aurantium* peels in some bakery products and reported that that products with natural aroma (Essential Oils) retained aroma better than the control biscuits over a period of storage. Therefore the addition of phytochemicals from the waste makes the muffins more attractive with better aroma and acceptance.

Table 5: Effect of supplementation of phytochemicals from kinnow on the sensory parameters of Muffins

3.4Physico-chemical parameters of selected Muffins

The physico-chemical parameters of selected muffins are shown in the Table 6. The moisture

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content showed an increasing trend in all prepared muffins. Mpo (34.45%) showed statistically higher content of moisture which is possibly due to its rich fiber content, that is having the property to absorb water (Maet al.2008).

There was a gradual decrease in the protein content in both Mp and Mpo whereas no significant ($p<0.05$) change was observed in the Mpo than the control. Fat percent decreased in all the muffins. This signifies the utilization of the waste for reducing the fat content in the muffins, making themmore edible for those candidates who want to reduce fats in their diets. A gradual change in crude fiber and ash content was also detected. Mpo and Mpcontained maximum fiber content as compared to the control and Mph. This may be due to high fiber and ash content in the peel and pomace powder as compared to the wheat flour thus providing more minerals and more health benefits(Nassaret al. 2008). The carbohydrate content increased as compared to Mc and Mph.

The weight of the prepared muffins increased significantly. This may be due to the higher moisture content of the Mp and Mph as compared to control. The volume of Mp and Mpo decreased significantly while as in case of Mph less change was detected as compared to control. According to Sharobaet al. (2013), volumes of cakes decrease with increase in fruits and vegetables by-product. Sudhaet al. (2016), while preparing muffins from apple pomace, observed that the volume and the specific volume decreased with increasing concentration of pomace.

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Table 6: Physio-chemical parameters of Muffins

3.3Effect of supplementation of peel, pomace and phytochemicals on the functional properties of muffins

Kinnow peel and pomace are the main by-products of the kinnow juice industry, which are rich sources of bioactive compounds having beneficial effects on the health. These functional properties are due to the presence of phytochemicals (phenolics, flavonoids, carotenoids etc). These phytochemicals have also been found to have preservative effect on the foods. Also the wheat flour is lagging these important components. Therefore if becomes imperative to utilize the kinnow waste for the production of foods having such effects. Muffins were prepared with peel, pomace and phytochemicals from kinnow (Table 7). The control muffins (Mc) were prepared by adding artificial antioxidant (BHA) to the flour within the permissible limits. There was a significant change in all the functional properties of the bakery products.

Muffins prepared with phytochemicals (Cp) exhibited higher TPC as compared to the others. TPC was more in all the supplemented bakery products other than the control. This may be due to the high content of polyphenolic compounds in the peel and pomace of kinnow. This was also reported by Sudhaet al. (2016), while preparing muffins from apple pomace. Flavonoids and carotenoids were increased in the supplemented samples than the control. This is due to higher content in peel, pomace and the extract which makes the muffins richer in these phytochemicals as compared to the control.

Antioxidants were shown higher in Mph followed by Mp (Table 7). This may be due to higher content of phenolics in the extracts than the peel. FRAP and DPPH showed the same trend. The colour values were increased by adding extracts to the muffins. Mc was lighter than the other treated items and hence more L value. Value of b* was increased due to bright red colour of the peel and extract. Values of

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a* were also increased while supplementing the muffins than the control. Kohajdováet al. (2011) reported a decrease in L value and increase in a* value while preparing bakery products from apple fiber.

Table 7: Phytochemical, antioxidant and color profile of Muffins

3.4Storage stability

3.4.1 Effect of storage period on the moisture content

Moisture content of muffins is considered as an important parameter that affects the final quality and acceptability of the product. Data showed significant decrease in the moisture content of muffins..

Owing to the high percentage of moisture content in muffins they tend to lose the moisture to the environment causing it to stale. Loss of moisture contents in case of muffins (Mpo and Mp) was slower as compared to Mc and Mph. The muffins containing peel and pomace showed less tendency to lose moisture than Mpo and Mc. This may be due to the reason that dietary fibers bond strongly water with it and making it difficult to evaporate.

There was not any significant difference between the moisture percent of Mph and Mc. One important mechanism is the migration of moisture from the starch granules into the interstitial spaces, gelatinizing the starch. The starch amylose and amylopectin molecules realign themselves causing re-crystallization. This results in stale muffins and its hard texture. Additionally, pleasant "fresh" flavor is lost to the air. The results were in agreement with Gupta & Singh (2005).

Fig 1: Effect of storage days on the moisture content of muffins

3.4.2 Effect of storage period on the free fatty acids

FFA is generally a measure of rancidity of the prepared product. FFA increased significantly during storage ($p<0.05$). Data showing the variation of FFA (% oleic acid) with storage is depicted in the

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Fig 2. The free fatty acid content was observed maximum in Mc as compared to Mp, Mph and Mpo during storage. This may be due to the reason that natural antioxidants from kinnow peel were superior to the artificial antioxidants (BHA), which are efficient to control rancidity. The phytochemicals caused an interactive effect making the free fatty acids unavailable. Stability of food products can be enhanced by the phenolic compounds of plant origin (Nadeemet al. 2017).Chughet al. (2015) also reported increasing FFA in low fat bakery products for ninety days of storage. The above study was also supported by Reddy et al. (2005). However the final observed FFA percent was found to be in limits as per BIS specifications.

Fig 2: Effect of storage days on the free fatty acids of prepared muffins

3.4.3 Effect of storage period on the peroxide value of muffins

Data representing the changing of peroxide value (meq 0_2/kg fat) in muffins during storage showed a significant change in the peroxide value in all the prepared muffins (Fig 3). Mph and Mp showed less PV than the corresponding muffins because of more antioxidant activity in Mp and Mphthan other products that may have inhibited the peroxide formation and hence can increase the shelf life of the product. Ashoush&Gadallah (2011) reported that phenolic and antioxidant activity increased by incorporating 10 percent of mango peel powder that may have mitigated the effect of peroxides. Reddy et al. (2005) reported an excellent control of PV in biscuits supplemented with some natural plant extracts than BHA during storage of biscuits. Additions of some freeze-dried plant extracts to high fat foods were reported effective in controlling lipid oxidation during storage (Mansourand&Khalil 2000).

Fig 3: Effect of storage days on the peroxide value of muffins

3.4.4 Effect of storage period on the Antioxidant activity of muffins

All the items exhibited a decreasing trend of antioxidant activity (Fig 4). Mp, Mpo and Mph, showed better antioxidant activities than that of control (Fig 4). Paul & Bhattacharyya (2015) while preparing cookies showed better antioxidant activities by the fortification of pomegranate powder. This

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may be due to higher concentration of phenolic compounds in the extracts that retained its activity. Addition of natural antioxidants can increase shelf-life of food products containing fats and oils. In addition, natural antioxidants are safe and impart health benefits to the consumer.

Fig 4: Effect of storage days on the antioxidant activity of muffins

Conclusion

The huge waste produced during the processing of kinnow in the form of pomace and peel is the potential sources of important bioactive compounds having beneficial health effects. Its valorization and utilization not only prevents the environmental pollution but also provide a better source of functional food. The addition of this waste (peel, pomace and derived phytochemicals) indicated that the 10% of peel, 5% of pomace and 4% of phytochemicals were acceptable and obtained better scores on the basis of sensory evaluation. Muffins fortified with peel and phytochemicals showed better stability and antioxidant activity due to the enriched phytochemicals in them.Thus, the utilization of kinnow waste and its phytochemicals as chief bioactive component with multidimensional properties will be an efficient, inexpensive, and environment friendly platform for the production of novel nutraceuticals.

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Table 1. Formulation used for the preparation of muffins

Ingredients	Amount
Flour	100 g
Sugar	95 g
Fat	60 g
Baking powder	2.5 g
Vanilla essence	2.5 ml
Egg	110 ml
Water	60 ml
Glycerol monosterate (GMS)	0.5 g

Table 2: Proximate composition of wheat flour, peel powder, pomace powder and phytochemical extracts

Parameters	Wheat flour	Peel powder	Pomace powder	Phytochemical extracts
Moisture (%)	11.26±0.11	9.67±0.58	11.53±0.50	-
Protein (%)	10.72±0.36	8.27±0.35	6.83±0.06	-
Fat (%)	2.29±0.05	2.60±0.10	5.11±0.58	-
Crude fiber (%)	0.48±0.05	9.06±0.27	3.53±0.15	-
Ash (%)	0.44±0.01	2.78±0.08	1.33±0.15	-

Data is represented as Mean±SD, where n=3

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Table 3: Effect of supplementation of dried peel powder of kinnow on the sensory parameters of muffins

Peel incorporated (%)	Colour	Texture	Flavour	Overall Acceptability
0	7.50±0.50[b]	8.33±0.57[a]	7.81±0.77[ab]	7.89±0.25[ab]
5	8.50±0.50[a]	8.16±0.76[ab]	8.16±0.76[a]	8.28±0.34[a]
10	8.66±0.28[a]	7.83±0.28[ab]	8.33±0.80[a]	8.27±0.25[a]
15	8.0±0.50[ab]	7.16±1.04[ab]	7.16±0.28[b]	7.44±0.53[bc]
20	7.83±0.30[b]	6.83±0.76[b]	6.66±0.76[b]	7.11±0.53[c]

Different alphabetical letters in superscript, in a column indicate the means differ significantly ($p<0.05$)

All values represent the mean of three replications ± SD (n =3).

Table 4: Effect of supplementation of dried pomace powder of kinnow on the sensory parameters of muffins

Pomace incorporated (%)	Colour	Texture	Flavour	Overall Acceptability
0	7.83±0.28[ab]	8.33±0.57[a]	8.00 ±0.68[a]	8.06 ±0.25[ab]
5	8.00±0.50[a]	8.67±0.28[a]	8.67±0.28[a]	8.44±0.38[a]
10	7.67±0.57[ab]	7.33±0.56[b]	7.33±0.57[b]	7.44±0.19[c]
15	7.33±0.57[ab]	6.67±0.29[c]	6.83±0.57[b]	6.94±0.34[d]
20	7.17±0.76[ab]	6.50±0.50[c]	6.33±0.28[bc]	6.67±0.44[d]

Different alphabetical letters in superscript, in a column indicate the means differ significantly ($p<0.05$)

All values represent the mean of three replications ± SD (n =3)

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Table 5: Effect of supplementation of phytochemicals from kinnow on the sensory parameters of Muffins

Phytochemicals incorporated (%)	Colour	Texture	Flavour	Overall Acceptability
0	7.66±0.58[b]	7.83±0.29[b]	7.33±0.60[b]	7.63±0.42[b]
1	8.00±0.00[ab]	8.00±0.01[ab]	7.50±0.50[b]	7.83±0.17[b]
2	8.00±0.00[ab]	8.16±0.30[a]	7.50±0.50[b]	7.90±0.25[b]
3	8.16±0.29[ab]	8.33±0.29[a]	8.00±0.00[ab]	8.16±0.17[a]
4	8.50±0.50[a]	8.00±1.00[ab]	8.33±0.29[a]	8.26±0.25[a]

Different alphabetical letters in superscript, across a column indicate the means differ significantly ($p<0.05$); all values represent the mean of three replications ± SD (n =3)

Table 6: Physio-chemical parameters of Muffins

Parameters	Mc	Mp	Mpo	Mph
Moisture (%)	31.27±0.06[c]	32.27±0.10[b]	34.45±0.01[a]	32.34±0.02[b]
Proteins (%)	9.30±0.13[a]	8.23±0.01[b]	6.61±0.07[c]	9.21±0.01[a]
Fat (%)	26.04±0.72[a]	23.83±0.61[b]	25.10±0.39[a]	25.8±0.03[a]
Crude fiber (%)	1.38±0.07[c]	3.57±0.10[a]	2.82±0.30[b]	1.37±0.02[c]
Ash (%)	0.98±0.02[c]	1.55±0.09[a]	1.33±0.01[b]	0.96±0.02[c]
Carbohydrates (%)	33.39±0.76[b]	35.67±0.72[a]	33.84±0.42[b]	33.23±0.01[b]
Weight (g)	32.61±1.10[c]	38.60±0.61[a]	35.23±0.72[b]	32.65±0.19[c]
Volume (cc)	248.33±2.88[a]	231.67±0.47[c]	238.33±1.13[b]	245.67±2.89[a]
Specific volume (cc/g)	7.61±0.10[a]	6.00±0.02[c]	6.76±0.05[b]	7.52±0.09[a]

Mc-Muffins prepared with artificial antioxidant (Control), Mp-Muffins supplemented with peel, Mpo- Muffins supplemented with pomace, and Mph- Muffins prepared with phytochemicals;Different alphabetical letters in superscript, in a row indicate the means differ significantly ($p<0.05$) and All values represent the mean of three replications ± SD (n =3)

Table 7: Phytochemical, antioxidant and color profile of Muffins

Samples	Mp	Mpo	Mc	Mph

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TPC (mg/g)		11.90±0.18a	9.61±0.34b	7.31±0.22c	12.34±0.07a
TFC (mg/g)		0.32±0.03b	0.20±0.03c	0.05±0.02d	0.50±0.09a
Carotenoids (mg/100g)		0.47±0.01b	0.22±0.01c	0.17±0.00c	0.82±0.01a
DPPH (%)		43.30±0.06b	28.72±0.01d	39.27±0.08c	59.71±0.08a
FRAP (mM/g)		19.74±0.41b	14.74±0.17c	16.11±0.33c	23.46±0.18a
(Colour)	L	42.44±11.83d	59.43±0.34b	63.73±0.06a	51.85±0.64c
	a*	3.39±0.01a	2.97±0.02b	2.63±0.04b	3.46±0.06a
	b*	26.62±0.27a	17.90±0.45b	13.55±1.19c	26.73±0.13a

Mc-Muffins prepared with artificial antioxidant (Control), Mp-Muffins supplemented with peel, Mpo-Muffins supplemented with pomace, and Mph- Muffins prepared with phytochemicals, TPC- Total Phenolic Content, TFC- Total Flavanoids Content;
Different alphabetical letters in superscript, across a column indicate the means differ significantly ($p<0.05$)
All values represent the mean of three replications ± SD (n =3)

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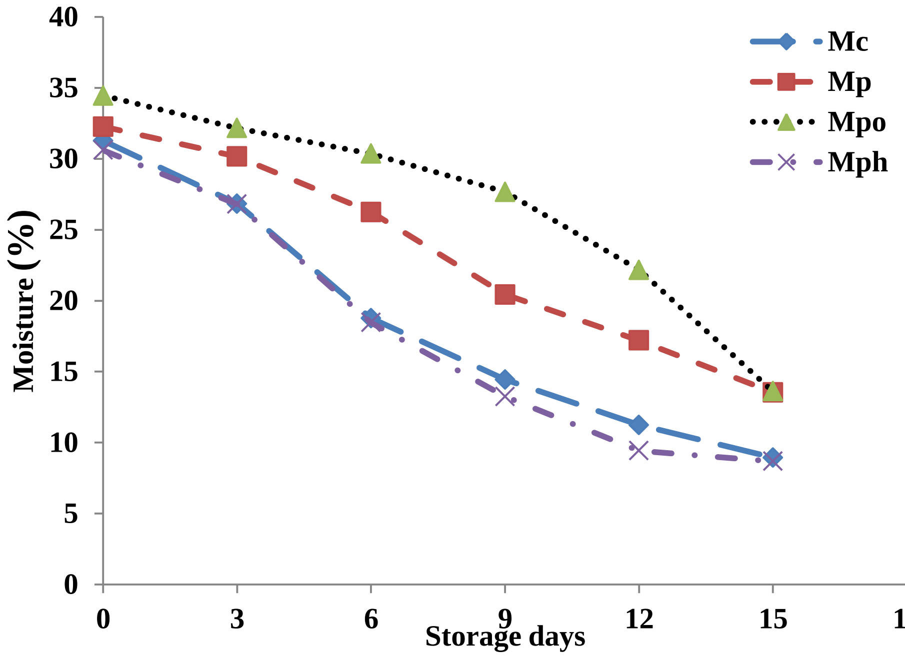

Fig 1: Effect of storage days on the moisture content of muffins

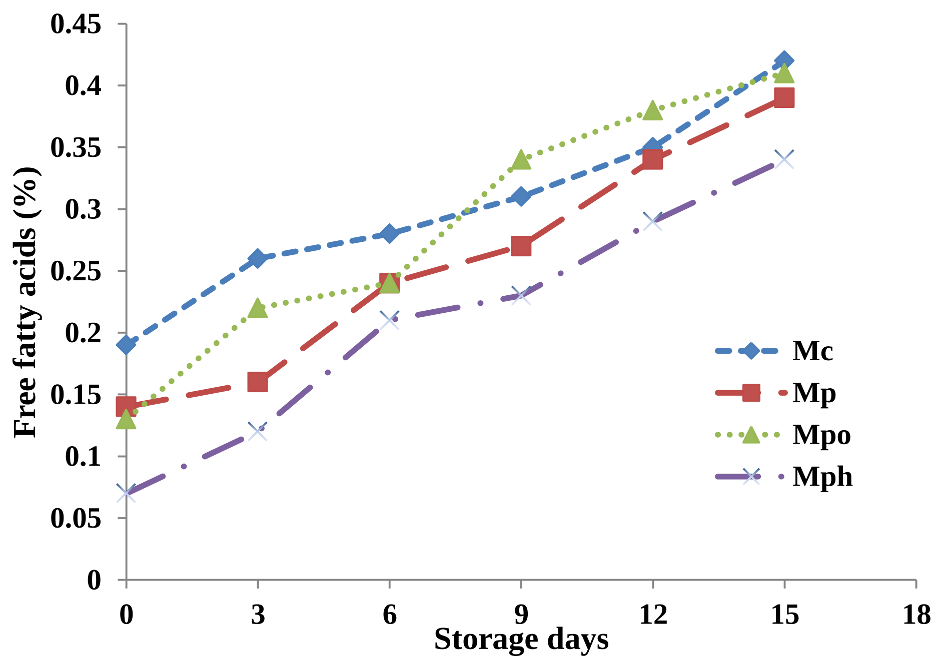

Fig 2: Effect of storage days on the free fatty acids of prepared muffins

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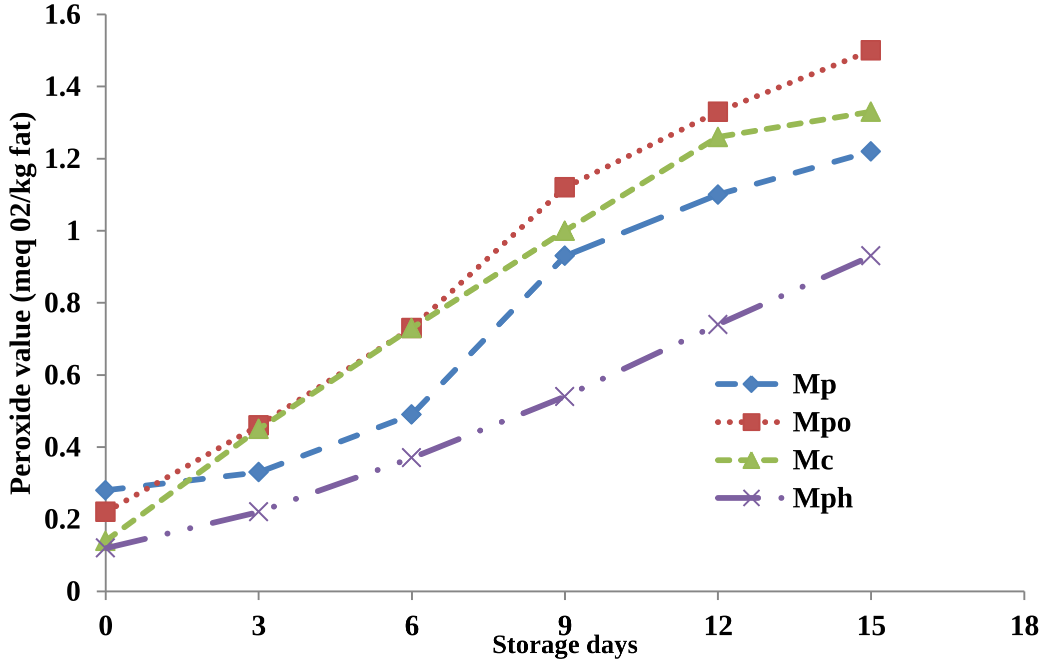

Fig 3: Effect of storage days on the peroxide value of muffins

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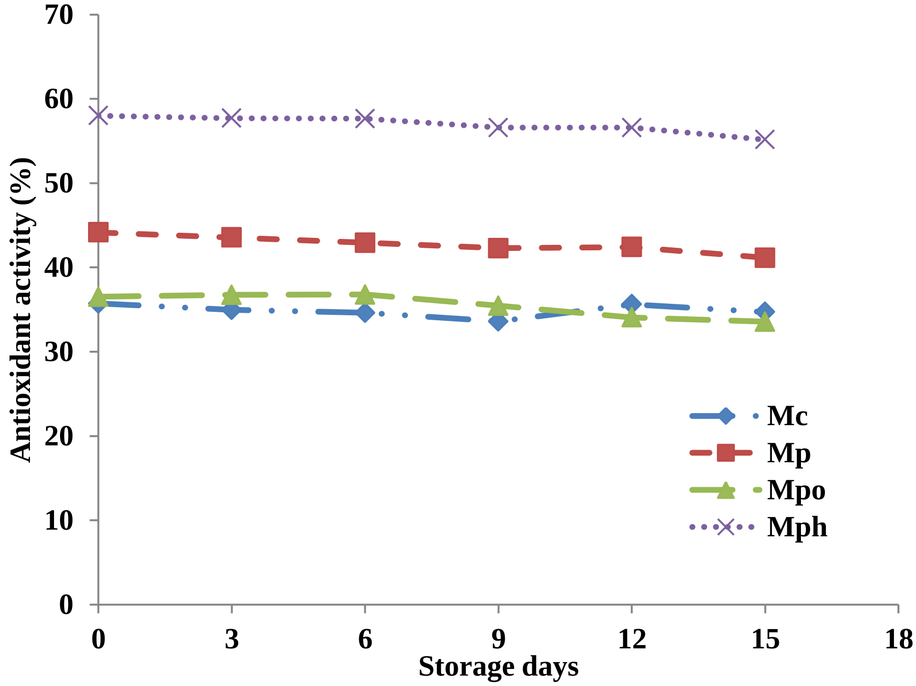

Fig 4: Effect of storage days on the antioxidant activity of muffins