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ORIGINAL ARTICLE

Value additon of kinnow industry byproducts for the preparation of fiber enriched extruded products

Gisha Singla[1] · Meena Krishania[1] · Pankaj P. Sandhu[1] · Rajender S. Sangwan[2] · Parmjit S. Panesar[3]

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Abstract In the present study dietary fiber enriched vermicelli from wheat flour supplemented with debittered kinnow industry by-products (pulp residue and pomace) has been developed. Functional, cooking and textural properties of both supplemented and unsupplemented vermicelli were evaluated. Vermicelli containing 15% debittered kinnow pulp residue and pomace showed minimum cooking loss (18.5, 20.0%) but higher swelling index (2.06, 1.87), water absorption capacity (153, 202 g/100 g) and optimal cooking time (9.34, 9.02 min). Firmness and fracturability of vermicelli supplemented debittered pulp residue (10.0 and 21.5) and pomace (16.7 and 16.1) was higher as compared to control sample (6.1 and 2.1) respectively. Further, redness, firmness, TPC, DPPH activity and water absorption capacity of vermicelli got increased with addition of debittered kinnow pulp and pomace. The utilization of debittered kinnow pulp and pomace in vermicelli can provide dual benefit like production of healthy food products along with solving the problem of solid waste disposal of kinnow industry byproducts.

Keywords Kinnow pulp residue · Kinnow pomace · Fiber enrichment · Functional properties · Textural properties · Vermicelli

Practical applications

High fiber vermicelli were prepared by incorporation of debittered kinnow pulp residue and pomace, were found rich in fiber, phyto-chemicals and antioxidants having various health benefits. Developed product will be helpful to manufacturers in providing active nutritional products and consumers demand for nutritional food products. Incorporation of debittered fiber enriched kinnow industry by-products (pulp residue and pomace) can provide dual benefits like production of healthy food products along with valorization of kinnow processing byproducts and waste management. So, by this product development a new paradigm in health and wellness will be fulfilled with respect to demand of functional foods and environmental management.

Introduction

"Kinnow," hybrid variety of king and willow mandarins (*Citrus nobilis* Lour × *C. deliciosa* Tenore) is major citrus fruit grown in a northern region of India, especially in Punjab, Haryana, Rajasthan and Himachal Pradesh (Sharma et al. 2007). The industrial processing of citrus fruits generates large amount (19 Mt annually) of peel waste (Bustamante et al. 2016). Kinnow industry by-products such as kinnow pomace includes peel and pulp residue, moreover peels are enriched with essential oils which have compounds with antimicrobial activity (Food-

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✉ Meena Krishania
er.mkrishania@gmail.com

[1] Center of Innovative and Applied Bioprocessing (CIAB), Sector-81, S.A.S Nagar, Mohali, Punjab 140306, India

[2] Academy of Scientific and Innovative Research (AcSIR), CSIR-Human Resource Development Centre, Sector 19, Ghaziabad, Uttar Pradesh 201 002, India

[3] Food Biotechnology Research Laboratory, Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Longowal, Punjab 148106, India

info 1999). Kinnow pulp residue waste is generally rich in cellulose (40%), hemi-cellulose (10%), pectin (2%) and anti-oxidants (15%), besides other ingredients. The main problem with the kinnow pulp is that it rapidly deteriorates due to the high moisture and sugar content, thereby being facile to quick growth of moulds and yeast. While drying the fresh pulp is a cost intensive step, heat treatment volatilises its essential/fragrant oils (Francisco et al. 2017). The dumping of by-products of juice processing industry can create various disposal and environmental problems and also result in loss of nutrients as these peels which are rich source of cellulose, pectin, hemicelluloses, lignin, essential oils and phenolic compounds (Hou et al. 2013).

The citrus fruit contains a high amount of better quality soluble dietary fiber as compared to other alternatives source such as cereals due to the presence of associated bioactive compounds with antioxidant properties in kinnow (Gorinstein et al. 2001). Dietary fiber is the edible part of plants which is resistant to digestion and adsorption in the small intestine (AACC 2000). Dietary fiber helps in the reduction of colorectal cancer, cardiovascular disease risk, and prevention of constipation, bowel transit time and production of short-chain fatty acids (Sabanis et al. 2009).

Various health benefits are associated with increased consumption of dietary fiber, such as prevention of heart disease, obesity and certain forms of cancer (Mann and Cummings 2009). Dietary fiber can help in reducing potential glycemic index and in performing various physiological functions (De Pilli et al. 2013). The average daily requirement of dietary fiber has been 25 g per day for women and 38 g per day for men. A daily intake of 20–30% dietary fiber has been suggested by nutritionists and experts (Food and Nutrition Board 2001, Washington, DC).

Dietary fiber from different fruits and cereals has been used as in extruded product formation including legume flours (Khan et al. 2013). Extruded products have gained importance due to bulk productivity, appearance, convenience and texture and extrusion technology is versatile, inexpensive, energy-efficient technique (Singh et al. 2016). Various properties such as quality, texture, an appearance of extruding products depend upon the chemical and structural changes took place during extrusion (Thakur et al. 2017).

Traditional extruded products comprised of moistened flour, high in starch which has been shaped into various forms such as vermicelli, spaghetti and macaroni. Nutritional value of extruded products can be increased by incorporation of dietary fiber sources into pasta formulation (Yadav et al. 2014). Different extruded products with enhanced nutrients have been made such as incorporation of pearl millet having barley and whey protein concentrate (Chillo et al. 2008), and with cereal enrichment (Kaur et al. 2012).

Due to ease of cooking and nutritional content, noodles have become a staple food in South-east Asia and China. About 12% of total global wheat produced has been utilized in extruded products (Gan et al. 2009). Now a days kinnow processing byproducts are major concern to the industry and environment due to the abundance production of kinnow fruits and it's processing. In view of this, the present investigation has been carried out for the valorization of kinnow industry byproducts to produce dietary fiber enriched vermicelli.

Materials and methods

Procurement of raw material

Raw material such as kinnow pulp residue and pomace were procured from Punjab Agro Juices Limited Village Alamgarh, Near Abohar, District Ferozepur (30°09′N, 74°12′E), Punjab, India. Analytical grade Food grade solvent–acetone and other chemicals for analysis have been purchased from Sigma-Aldrich Company Ltd. (St Louis, MO, USA).

Physico-chemical characterization of kinnow pulp residue, pomace and wheat flour

Physico-chemical analysis of kinnow pulp residue, pomace and refined wheat flour has been carried out for its different constituents/nutritional and functional properties such as estimation of moisture content by using moisture analyzer, (MA35, Saritorius), protein (Lowry et al. 1951). The crude fat, total carbohydrates, ash content, dietary fiber content has been determined according to methods prescribed by association of analytical communities (AOAC 2000). Total phenolic content has been determined by Folin–Ciocalteu method (McCune and Johns 2002), DPPH activity according to a method proposed by Shimada et al. (1992).

Debittering of kinnow pulp residue and kinnow pomace

The debittering of kinnow pulp residue and pomace was carried out using solvent treatment method (Elfalleh et al. 2012). Experiments were performed using acetone (food grade solvent) 25 °C. The sample: solvent (1:5) mixture was homogenized for 3 h at 2000 rpm. An extract was centrifuged (Eppendorf Centrifuge 5810 R) at 8000 rpm for 3 min at ambient temperature. The supernatant was collected and the solvent was recovered using rotary evaporator (IKA, HB 10 Control) system under vacuum at a temperature of 45 °C which was then stored for further reuse. Maximum debittered kinnow pulp residue and pomace on basis of decrease in naringin and limonin content has been obtained in acetone treated sample. Samples were then air dried for overnight (12 h) and ground for further use (Gisha et al. 2018).

Vermicelli production

Dietary fiber enriched debittered kinnow pulp and pomace was supplemented at various concentrations (5–20%) in extruded products as shown in Table 1. The basic raw material used in vermicelli making was refined wheat flour. Debittered kinnow pulp residue and pomace has been substituted with refined wheat flour at various combinations range 5–20 g/100 g. Vermicelli without any substitution of debittered kinnow pulp residue and pomace were referred to as a control sample. The semi-solid dough having uniform consistency has been made by using a blend of different mixtures with optimal addition of 30 ml water which was then extruded in vermicelli making machine having a single screw (Model: Dolly La Monferrina, Italy). Extruded vermicelli formed was cut into pieces of uniform length (2 cm) with knife moving around outer side of die surface. The final product formed was dried at 60 °C for 3 h having moisture content 5.68% and then stored in low-density polyethylene (LDPE) bags for further analysis.

Quality evaluation of vermicelli

Optimal cooking time (OCT)

Samples (5 g) were cooked in 150 ml of water until the inner white portion of vermicelli after squeezing between two glass plates got disappeared (AOAC 2000). Time taken for gelatinization of starch has been noted and measurements have been performed in triplicate.

Water absorption capacity

Water absorption capacity (WAC) (g/100 g) has been measured using the method as described by Petitot et al. (2010). The weight of vermicelli samples was taken before and after cooking. Measurements have been performed in triplicate. Water absorption has been calculated by using the equation:

$$\text{Water Absorption (g/100 g)} = \frac{\text{Wt. of cooked product} - \text{Wt. of raw product}}{\text{Wt. of raw product}}$$

Swelling index

Calculations of the swelling index have been evaluated as per the method of Cleary and Brennan (2006). In this method, cooked samples were dried at 105 °C for 16 h and then measurements have been performed in triplicate using the equation:

$$\text{Swelling Index} = \frac{\text{Wt. of cooked product} - \text{Wt. of product after drying}}{\text{Wt. after drying}}$$

Table 1 Fraction of raw materials used in preparation of vermicelli

Sample	Debittered pulp residue and pomace (g/100 g)	Water (ml)	Refined flour (g/100 g)
Control 1 (refined flour)	–	30	100
Pulp residue (5%)	5 ± 0.12	30	95 ± 0.09
Pulp residue (10%)	10 ± 0.10	30	90 ± 0.10
Pulp residue (15%)	15 ± 0.02	30	85 ± 0.01
Pulp residue (20%)	20 ± 0.01	30	80 ± 0.03
Pomace (5%)	5 ± 0.03	30	95 ± 0.01
Pomace (10%)	10 ± 0.01	30	90 ± 0.21
Pomace (15%)	15 ± 0.10	30	85 ± 0.02
Pomace (20%)	20 ± 0.01	30	80 ± 0.04

Values are the Mean ± SD of three replications

Values in different columns differ significantly ($P \leq 0.05$)

LSD least significant difference at $P < 0.05$

Cooking loss

The cooking loss of vermicelli has been described by Chillo et al. (2008). After cooking vermicelli residual water left after cooking was collected and then oven dried at 105 °C for 16 h. A weight of residue left has been taken. The cooking loss has been expressed as a percentage of starting material. Triplicate measurements have been taken.

$$\text{Cooking loss } (\%) = \frac{\text{Wt. of dry residue} \times 100}{\text{Wt. of dry product}}$$

Textural characteristics

Textural properties such as the firmness of cooked and uncooked vermicelli have been determined using by estimating the flexural strength by taking 5 random observations using texture analyzer (TA.HD plus, Stable Microsystems, UK).which causes their compression (60%) with a probe (P/75). Cooked samples were rested for 10 min before analysis. Method 66-50 (AOAC 2000) has been used with slight modifications to determine firmness, known as maximum cutting force (N) (Foschia et al. 2014). The texture analyzer settings for vermicelli were fixed (pre-test speed 3 mm/s, test speed 3 mm/s, post-test speed 5 mm/s, initial distance 10 mm/s, final distance 100 mm; trigger type, auto, 5 g). Mean value of all replications has been taken.

Colour

The colour properties have been measured using coloflex EZ, Hunter lab having 45°/0° geometry has been used for colour readings on the surface of cooked and uncooked vermicelli. Results were expressed as L* (brightness), a* (redness) and b* (yellowness). Calibration of instrument has been made using a standard white tile ($L^* = 98.03$, $a^* = -0.23$, $b^* = 0.25$).

Statistical analysis

Statistical significance was inspected and compared by using the least significant difference (LSD) test at $P < 0.05$ and ANOVA. All statistical analyses were performed using Minitab Statistical software (Version 14.12.0, Minitab, State College, PA., U.S.A.).

Results and discussion

Physico-chemical characteristics of kinnow pulp residue and pomace

Physico-chemical characteristics of kinnow pulp residue and pomace are shown in Table 2. Dietary fiber in kinnow pulp residue and kinnow pomace was 60.4 and 45.11% respectively while protein content was 10.32 and 11.78%, respectively. Total carbohydrates in kinnow pomace were slightly higher (74.35%) than kinnow pulp residue (73.84 mg/g) and ash content in kinnow pulp residue was found to be 0.48% and in kinnow pomace it was 0.59%. The higher ash content in pomace can be due to high mineral content (Fallahi et al. 1985).

Debittering of kinnow pulp residue and pomace

Acetone, food grade solvent has been used for the debittering of kinnow pulp residue and pomace. The supernatant after treatment was collected and the solvent was recovered using rotary evaporator system under vacuum and stored for further reuse. Since the bitterness causing compounds were solvent soluble so it was observed the residual solvent recovered after treatment of kinnow pulp residue and pomace contained high amount of bitterness causing compounds, i.e. naringin and limonin 3.40, and 5.97 mg/g and 8.40, and 17.14 mg/g respectively.

Sensory analysis of debittered kinnow pulp residue and kinnow pomace has been done after organo-solvent treatment. Panelists including students and researchers from Department of Food Engineering and Nutrition at Center of Innovative and Applied Bioprocessing, Mohali, Punjab were selected for sensory analysis regarding appearance, taste color, aroma, body/texture, flavor, astringency and overall acceptability (Amerine et al. 1965). Overall acceptability of debittered kinnow juice industry by-

Table 2 Chemical composition of kinnow industry by-products

	Refined flour (%)	Pulp residue (%)	Pomace (%)
Protein	10 ± 0.12	10.32 ± 0.15	11.78 ± 0.2
Carbohydrates	75 ± 0.14	73.84 ± 0.11	74.35 ± 0.16
Fat	0.7 ± 0.02	4.2 ± 0.03	1.61 ± 0.06
Ash	1.08 ± 0.04	0.48 ± 0.01	0.59 ± 0.02
Crude fiber	0.01 ± 0.01	17.82 ± 0.02	18.75 ± 0.04
Dietary fiber	0.01 ± 0.01	60.4 ± 0.01	45.11 ± 0.01

Values are the mean ± SD of three replications

Values in different columns differ significantly ($P \leq 0.05$)

LSD least significant difference at $P < 0.05$

products (on basis of sensory attributes) on five point hedonic scale (1 = extremely dislike to 5 = extremely like) was carried out. The original flavor of kinnow without bitterness was observed in acetone-treated pulp residue (debittered, 5) and acetone-treated pomace was also obtained (4) hedonic reading. Total phenolic content was found to be 1.95 mg/g and 3.45 mg/g in acetone-treated pulp residue and pomace. DPPH activity was found to be 23.15 and 42.45% in acetone-treated kinnow pulp residue and pomace, respectively (Gisha et al. 2018).

Preparation of vermicelli and quality analysis

Different concentrations of know industry byproducts were supplemented in refined wheat flour for the preparation of vermicelli. Nutritional analysis of debittered pulp residue and pomace supplemented vermicelli has been shown in Table 3. It has been found that with increase in concentration of debittered kinnow pulp residue and debittered kinnow pomace (5–20%) in vermicelli, fat content in debittered pulp residue supplemented vermicelli varied from 0.2 to 0.32%, and in case of debittered kinnow pomace supplemented vermicelli it varied from 0.20 to 0.22%, ash content varied from 1.08 to 1.89% and 1.28 to 1.72% in debittered kinnow pulp residue and pomace supplemented vermicelli respectively. Protein content in debittered pulp residue and pomace supplemented vermicelli increased from 9.25 to 10.98 and 9.36 to 11.01% respectively with an increase in concentration. The crude fiber content varied from 0.85 to 1.63% in debittered pulp residue containing vermicelli and from 1.48 to 2.50% in debittered pomace containing vermicelli.

Functional properties

The cooking indices such as optimal cooking time (OCT), water absorption capacity (WAC), swelling Index and cooking loss of prepared vermicelli were studied (Table 4). It has been observed that time taken by control samples using refined wheat flour were 11.15 min and in debittered kinnow pulp residue supplemented vermicelli (5–20%), time duration decreased from 10.45 to 9.05 min. Similarly, in the case of debittered kinnow pomace supplemented vermicelli (5–20%), the time required for optimal cooking increased from 9.50 to 8.45 min. It has also been reported in the previous literature that optimal cooking time got decreased with a substitution of dietary fiber such as inulin, durum bran and bean flour in extruded products (Aravind et al. 2012).

Swelling index of the vermicelli supplemented with debittered kinnow pulp and pomace fiber was higher as compared to non-supplemented vermicelli as dietary fiber has greater capacity to absorb and retain water within starch-protein polysaccharide network (Foschia et al. 2015). Swelling index of debittered kinnow pulp residue supplemented vermicelli increased with increase in concentration of pulp residue (5–20%) from 1.5 to 3.33. Similarly, swelling index got increased from 1.71 to 3.16 in debittered kinnow pomace supplemented vermicelli (5–20%). It has been reported that temperature, pH, porosity and particle size of components are the factors responsible for hydration property of dietary fiber and fruits juices by-products have more water holding capacity as compared to cereal derivatives (Singh et al. 2015).

Water absorption capacity (WAC) was 73.5 g/100 g in control vermicelli. WAC increased from 101 to 160 g/100 g and 108 to 212 g/100 g with supplementation of

Table 3 Nutritional composition of vermicelli

Sample	Ash content (%)	Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)
Control 1 (refined flour)	0.66 ± 0.04	3.14 ± 0.11	10 ± 0.11	0.7 ± 0.02	0.98 ± 0.01
Pulp residue (5%)	1.08 ± 0.02	4.40 ± 0.10	9.25 ± 0.13	0.2 ± 0.01	0.85 ± 0.02
Pulp residue (10%)	1.77 ± 0.01	4.36 ± 0.09	10.11 ± 0.12	0.31 ± 0.02	1.25 ± 0.03
Pulp residue (15%)	1.82 ± 0.02	4.29 ± 0.12	10.45 ± 0.11	0.31 ± 0.03	1.56 ± 0.02
Pulp residue (20%)	1.89 ± 0.04	4.25 ± 0.11	10.98 ± 0.13	0.32 ± 0.01	1.63 ± 0.01
Pomace (5%)	1.28 ± 0.03	3.54 ± 0.10	9.36 ± 0.14	0.2 ± 0.02	1.48 ± 0.02
Pomace (10%)	1.57 ± 0.02	3.65 ± 0.11	10.10 ± 0.11	0.21 ± 0.03	1.98 ± 0.03
Pomace (15%)	1.69 ± 0.03	3.98 ± 0.12	10.34 ± 0.14	0.21 ± 0.02	2.21 ± 0.01
Pomace (20%)	1.72 ± 0.04	3.72 ± 0.10	11.01 ± 0.13	0.22 ± 0.01	2.50 ± 0.02

Values are the mean ± SD of three replications

Values in different columns differ significantly ($P \leq 0.05$)

LSD least significant difference at $P < 0.05$

Table 4 Functional properties of vermicelli samples before and after cooking

Sample	Cooking time (min)	Swelling index	Water absorption capacity (g/100 g)	Cooking loss (%)
Control 1 (refined flour)	11.15	1.04 ± 0.12	73.5 ± 0.5	15 ± 0.14
Pulp residue (5%)	10.45	1.5 ± 0.4	101 ± 0.37	15.5 ± 0.16
Pulp residue (10%)	10.03	1.87 ± 0.18	115.5 ± 0.41	16.3 ± 0.13
Pulp residue (15%)	9.34	2.06 ± 0.24	153 ± 0.36	18.5 ± 0.08
Pulp residue (20%)	9.05	3.33 ± 0.13	160 ± 0.38	20.3 ± 0.14
Pomace (5%)	9.50	1.71 ± 0.15	108 ± 0.47	17.02 ± 0.01
Pomace (10%)	9.14	2.66 ± 0.18	127.5 ± 0.43	18.05 ± 0.03
Pomace (15%)	9.02	1.87 ± 0.27	202.5 ± 0.48	20.08 ± 0.14
Pomace (20%)	8.45	3.16 ± 0.35	212.5 ± 0.43	22.6 ± 0.12

Values are the mean ± SD of three replications

Values in different columns differ significantly ($P \leq 0.05$)

LSD least significant difference at $P < 0.05$

vermicelli with debittered kinnow pulp residue and kinnow pomace. Higher the fiber content, stronger will be its water absorption capacity (Kaur et al. 2012). Dietary fiber from different fruits and cereals has shown variable effect on water absorption capacity because of difference in their structure and particle size (Chen et al. 1988).

The cooking loss for un-supplemented vermicelli was found to be 15% that increased from 15.5 to 20.3% and 17.02 to 22.6%, respectively with supplementation of dietary fiber enriched debittered kinnow pulp residue and pomace. The integrity of the protein matrix has been influenced by uniform diffusion of water inside vermicelli which resulted in a cooking loss. The cooking loss was also reported to be affected by protein content (Sissons 2008) and type of fiber supplemented. Cooking loss got increased with an increase in fiber content as compared with control sample as protein-starch matrix got disrupted and a competitive hydration capacity of fiber (Foschia et al. 2015).

Textural analysis

Textural properties such as firmness and fracturability of cooked and uncooked vermicelli as affected by supplementation of debittered pulp residue and pomace is shown in Table 5. The results indicated that both hardness and fracturability increased with the addition of debittered pulp residue (10.01 and 21.582) and pomace (16.738 and 16.128) as compared to control sample (6.106 and 2.165). Firmness and fracturability of debittered pomace supplemented vermicelli was higher as compared to debittered pulp residue supplemented vermicelli. The results reflected that vermicelli structure was dependent upon the type, amount of dietary fiber added and also upon the conditions which was used for vermicelli production (Juszczak et al. 2012).

Table 5 Textural properties of un-cooked and cooked vermicelli

Sample	Hardness (N)	Fracturability (N)
Uncooked samples		
Control (refined flour)	6.106 ± 0.4	2.165 ± 0.38
Pulp residue (15%)	10.01 ± 0.38	21.582 ± 0.34
Pomace residue (15%)	16.738 ± 0.35	16.128 ± 0.38
Cooked samples		
Control (refined flour)	1.927 ± 0.4	0.744 ± 0.4
Pulp residue (15%)	4.30 ± 0.37	2.30 ± 0.35
Pomace (15%)	7.18 ± 0.38	1.89 ± 0.38

Values are the mean ± SD of three replications

Values in different columns differ significantly ($P \leq 0.05$)

LSD least significant difference at $P < 0.05$

Colour

The L*, a*, b* values of vermicelli before and after cooking has been shown in Table 6. The L value of control sample (in case of uncooked sample) was found to be 41.44, whereas the L* value of acetone treated pulp residue and pomace supplemented vermicelli was found to be significantly lower, which was 31.65, 21.65 respectively. The a* value (redness parameter) of debittered kinnow industry by-products supplemented vermicelli was higher (3.79, 9) as compared to control sample (1.34), b* value was also found to be higher 25.07 and 27.19 in uncooked debittered pulp residue and pomace supplemented vermicelli as compared to control uncooked sample (13.49).

Table 6 Colour measurements of vermicelli samples before and after cooking

Sample	L*	a*	b*
Un-cooked samples			
Control (refined flour)	41.14 ± 1.39	1.34 ± 1.01	13.49 ± 0.67
Pulp residue (15%)	31.65 ± 1.31	3.79 ± 1.03	25.07 ± 0.34
Pomace (15%)	21.65 ± 1.28	9 ± 0.99	27.19 ± 0.32
Cooked samples			
Control (refined flour)	39.91 ± 1.32	0.24 ± 0.76	11.07 ± 0.56
Pulp residue (15%)	43.28 ± 1.35	2.46 ± 0.65	24.05 ± 0.41
Pomace (15%)	38.57 ± 1.21	4.67 ± 0.47	23.52 ± 0.23

Values are the mean ± SD of three replications

Values in different columns differ significantly ($P \leq 0.05$)

LSD least significant difference at $P < 0.05$

However, cooked vermicelli supplemented with debittered kinnow by-products showed no significant difference in L* values. It has been observed that L* values were 43.28, 38.57 in debittered pulp residue and pomace supplemented vermicelli and 39.91 in un-supplemented cooked vermicelli, whereas a* value was higher (2.46 and 4.67) in debittered pulp residue and pomace supplemented vermicelli than un-supplemented cooked vermicelli (0.24). However, b* value of cooked pulp residue and pomace supplemented vermicelli was almost similar (24.05, 23.52) but higher than un-supplemented cooked vermicelli (11.07). The yellow colour of prepared vermicelli can be the desirable attribute of the product for its consumer acceptance. In previous studies on egg pasta produced from oat, teff and wheat flour, dietary fiber enriched extruded products were darker as compared to the control sample (Hager et al. 2013).

From above experiments, it was observed that vermicelli having 15% substitution of debittered kinnow pulp residue and pomace in refined flour showed minimum cooking loss, high L*, a*, b* values in case of cooked samples, maximum water absorption capacity and optimal cooking time.

Conclusion

The results illustrate that vermicelli made with the incorporation of debittered pulp residue and pomace (15% concentration) was rich in fiber, phytochemicals and antioxidants as compared to control sample. It was observed that the addition of debittered kinnow pulp residue and pomace led to enhancement in total dietary fiber, TPC, DPPH activity, decrease the cooking time, increase swelling capacity and water absorption capacity and minimum cooking loss. The debittered kinnow pulp and pomace residue enriched vermicelli has appealing orange colour as compared to the control samples. Thus, the supplementation of debittered kinnow pulp and pomace in vermicelli can provide dual benefits, i.e. production of fiber rich food products as well as value addition of kinnow processing byproducts which otherwise are major concern to the environment.

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