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Development of gluten-free bakery products enriched with bio-waste from carrot juice processing

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Abstract
Pseudocereals such as buckwheat, amaranth and quinoa are gluten-free grains loaded with essential nutrients and bioactive compounds that render them effective in reducing the risk many degenerative diseases such as cancer, CVD, diabetes etc. The development of pseudocereal-based cake involved blending of carrot pomace flour with buckwheat, quinoa and amaranth flour in different proportions. Carrot pomace flour up to a concentration of 34% was used to replace pseudocereal flours and based on the sensory scores the best combination was selected for evaluation. Overall acceptability scores varied with the pseudocereal flour used as, buckwheat flour and quinoa flour at the levels of 72%, while amaranth flour at the levels of 66% gave best results. Supplementation of products with carrot pomace considerably improved the fibre and carotenoid content of developed products, while a slight reduction phenol content and antioxidant activity was observed in quinoa and buckwheat-based cake. The developed products are the perfect example of bio-waste utilization, in addition to being gluten free in nature.

Keywords: Pseudocereals, gluten-free, valorization, carotenoids, carrot pomace, antioxidant activity

1. Introduction

Pseudocereals are seed producing dicotyledonous plant species, similar to the cereal grains in their function and composition (Alvarez-Jubete, Wijngaard, Arendt, & Gallagher, 2010) [3]. These are underutilized crops but awareness about their nutritional benefits has led their increased cultivation worldwide. Pseudocereals primarily include buckwheat, amaranth and quinoa, out of which amaranth (*Amaranthus* spp.) and quinoa (*Chenopodium quinoa*) were chief crops for the pre-Colombian culture in Latin America and buckwheat (*Fagopyrum esculentum*) traces its origin from Central Asia. The nutritive value of pseudocereal grains is chiefly associated to the presence of high-quality protein and dietary fibre. The protein fraction of pseudocereal flour is primarily composed of albumin and globulin, while the prolamin and glutelin-like proteins are present in small quantities. Moreover, gluten forming prolamins such gliadins and related protein fractions are completely absent, rendering these grains essentially gluten-free (Alencar, & Oliveira, 2019) [2]. This gluten-free nature of pseudocereal grains makes them appropriate for formulation of gluten-free diet for celiac disease patients. Apart from this, isoflavonoids and phytosterols of pseudocereals exhibit various health benefits in human beings such as reduced risk of cardiovascular diseases, anti-cancer and anti-inflammatory activities (Alencar, & Oliveira, 2019) [2]. Further, low glycemic index (GI) of pseudocereals make them suitable choice for the patients suffering from Type-2 diabetes as elevated GI is associated with instant rise in blood glucose levels.

Carrot (*Daucus carota*) is a highly nutritious vegetable rich in fibre, protein, carbohydrate, minerals (iron, calcium, manganese, sodium, phosphorus, magnesium, copper, zinc and potassium) and vitamins (riboflavin, thiamine, niacin and vitamin C), which was first domesticated in Afghanistan and later spread towards Europe and Asia (Stolarczyk, & Janick, 2011) [24]. Carrots owing to their carotenoids and polyphenols exhibit excellent antioxidant activity and aids in reducing the risk of cancer, stroke, heart disease and high blood pressure (Mounika & Maloo, 2018) [19]. Consumer demand for healthy fruit and vegetable juices has led to an increase in carrot juice production, as a consequence to which an adequate quantity of pomace is produced. Carrot pomace (CP), a bio-waste generated in the carrot juice processing industry, accounts for the 50% of raw material and is abundant in valuable compounds such as carotenoids, neutral sugars, dietary fibre and uronic acids (Sharma, Karki, Thakur, & Attri, 2012) [23]. As, the modern-day consumer is becoming aware of the health issues, the need for the nutritionally enriched and high-quality products has increased. Meanwhile, the increased consumption of bakery products such as bread, cake and biscuit all over the world makes them an important carrier of various functional ingredients (Pinto, Castro, Vicente, Bourbon, & Cerqueira 2014) [21]. Bakery products prepared using refined wheat flour are functionally inferior and lack required nutrition. Thus, preparation of baked products using buckwheat, amaranth, quinoa and partially blending it with carrot pomace flour (CF) helps in improving their nutritional and functional status, as well finding a value addition method for the profitable utilization of carrot bio-waste. Keeping in view the above-mentioned properties of pseudocereals and CP, gluten-free functional bakery products were developed by integration with CF and were evaluated for quality and safety attributes.

2. Material and Methods

2.1 Raw material

Pseudocereal grains i.e. buckwheat, quinoa and amaranth were procured from National Bureau of Plant Genetic Resources (NBPGR) Research Station, Shimla, while carrots were purchased from fruit and vegetable market at Solan, Himachal Pradesh. The ingredients required such as sugar, refined oil, salt, baking powder, baking soda, eggs and polyethylene pouches were procured from local market at Nauni, Solan and other materials like chemicals required for product analyses were purchased from M/S Loba International Scientifics and Surgical, Solan.

2.2 Preparation of carrot pomace flour

The CF was prepared by extracting the juice using hydraulic press, followed by collecting the left-over bio-waste and subjecting it to steam blanching (4 min) and treatment with 1000 ppm potassium metabisulphite (KMS). Pomace was shifted to drying trays and dried in mechanical cabinet drier for 15 h at 60 ± 5 °C. The dried pomace was grinded and sieved through 30 mesh- sieve (Fig. 1).

Fig 1: Flow sheet for the preparation of carrot pomace flour

2.3 Preparation of pseudocereal-based cake

The cake was prepared by following the recipe standardized by Kaur, Kaur, & Grover (2018) [15], with slight modifications. Refined oil and powdered sugar were mixed together and beaten until the mixture became light and fluffy. Eggs were beaten separately and added to the above mixture with continued mixing. Dry ingredients i.e. flour and baking powder were mixed properly and added to the fluffy mass. The whole mixture was whipped constantly to achieve a batter of desired consistency. The batter was poured in pre-greased baking mould and after proper leveling and setting, was baked in pre-heated oven at 200˚C for 30 min. Cake after baking was allowed to cool at room temperature, prior to packaging.

2.4 Standardization of different proportion of pseudocereals and carrot pomace flour for the preparation of cake

Three types of cake were prepared using each, buckwheat, amaranth and quinoa flour. Carrot pomace at the levels of 0, 10, 16, 22, 28 and 34% was used to replace the pseudocereal flour (PF) and prepared products were evaluated in terms of sensory parameters by a panel of 10 judges on a 9-point Hedonic scale and the treatment having highest overall acceptability was selected for the future studies.

2.5 Physico-chemical analysis

2.5.1 Physical characteristics

The samples were weighed on an electronic weighing scale and the sample weight was expressed in grams (g) per unit. A Vernier caliper (Mitutoyo Absolute Digimatic Caliper) was used to measure the diameter of the cake and was expressed in mm. Cake volume was measured using rapeseed displacement method described by Greene & Bovell-Benjamin (2004) [12]. The thickness (distance between top and bottom surface) was expressed in mm and was determined using a Vernier caliper. Spread ratio was determined by dividing the average value of width with the average value of thickness. Density determined as the ratio of the weight and volume of the sample. The batter yield of the samples was measured as the weight of product divided by weight of batter, multiplied by 100 and was expressed as percentage. Baking loss is the loss in mass of a product as a result of baking. The baking loss rate of the products was calculated as per the method given by Mrabet *et al.* (2015) [20], using the formula given below:

$$\text{Baking loss rate (\%)} = \frac{\text{Weight of batter} - \text{Weight of cake}}{\text{Weight of batter}} \times 100$$

2.5.2 Chemical Characteristics
The moisture content of the sample was determined by drying the weighed sample in hot air oven at 70 ± 2 ^{0}C till it had a constant weight (Ranganna, 2009). Ash content of the sample was determined using the method suggested by Ranganna (2009). The samples were burned in muffle furnace at 550 ± 2˚C for 3-4 h to obtain carbon free white ash and ash content was calculated. Fat content of the sample was estimated using the automatic SoxTron fat extraction instrument (Model: Sox-2 version 0.1) by referring to the method given in AOAC (2012). Crude fibre content of sample was evaluated using FibroTRON-FRB-2 instrument, according to the procedure followed in AOAC, 2012 [5]. The total carbohydrate content was determined by subtraction method explained by Ranganna (2009). Protein content was determined by following the method given in AOAC (2012) [5] using semi-automatic instrument i.e. KjelTRON (KDIGB 6M & KjelDISTEA). Total protein content was calculated by multiplying % nitrogen by factor 6.25. Reducing and total sugar content was determined by volumetric method described by Lane & Eynon (1923) [16]. The total carotenoids content of products was estimated by solvent extraction method described by Ranganna (2009). Sample was extracted using acetone and after separation the optical density of separated colored layer was measured at 452 nm using UV-VIS spectrophotometer. Total phenol content of samples was determined by the method given by Bray & Thorpe (1954) [7]. The optical density of the samples was measured at 650 nm using UV-VIS spectrophotometer (Shimadzu, Japan). The concentration was determined as per the standard procedure from the standard curve. Antioxidant potential of raw materials as well as products developed was estimated using the DPPH radical scavenging method described by Brand-Williams, Cuvelier, & Berset (1995) [6]. Using methanol as blank, the optical density of sample was measured at 515 nm (till absorbance became steady) with UV-VIS spectrophotometer and remaining DPPH concentration was calculated.

2.6 Sensory evaluation
Sensory evaluation of the developed product (pseudocereal based CF enriched cake) was conducted using 9-point Hedonic scale method (Amerine, Pangborn, & Roessler 1965). The products were subjected to sensory evaluation by panel of 10 judges including faculty members and post-graduate students of Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry.

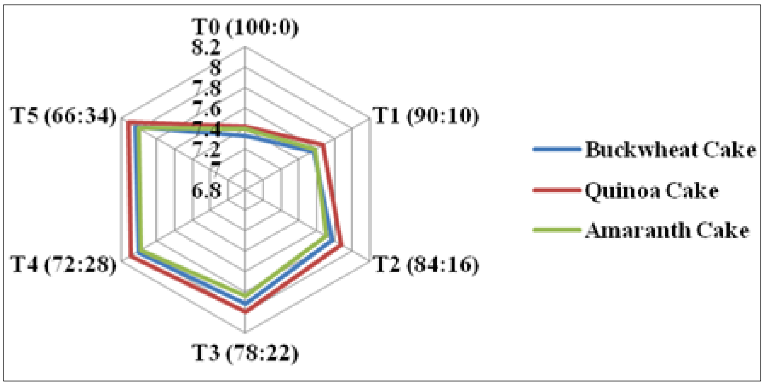
2.7 Statistical analysis
The data for the physico-chemical evaluation of pseudocereal and carrot pomace-based bakery products before and during storage were analyzed statistically by using Complete Randomized Design (CRD) specified by Cochran & Cox (1967) [10].

3. Results and Discussion
3.1 Proximate composition of the raw material
The data pertaining to the chemical composition of PFs and fresh as well as dried CP used for the preparation of cake are presented in Table 1. Results pertaining to chemical composition of pseudocereal flours could be supported by observations of De Bock *et al.* (2021) and Alvarez-Jubete *et al.* (2010) [11, 3]. Observations could be validated by research performed by Catana *et al.* (2019) [9] that highlighted 7.12-7.55% moisture, 6.4-7.28% ash, 6.55-9.21% protein and 10.70-13.65 mg/ 100 g beta-carotene in CF, however comparatively higher values for phenols and antioxidant activity were recorded by the researcher.

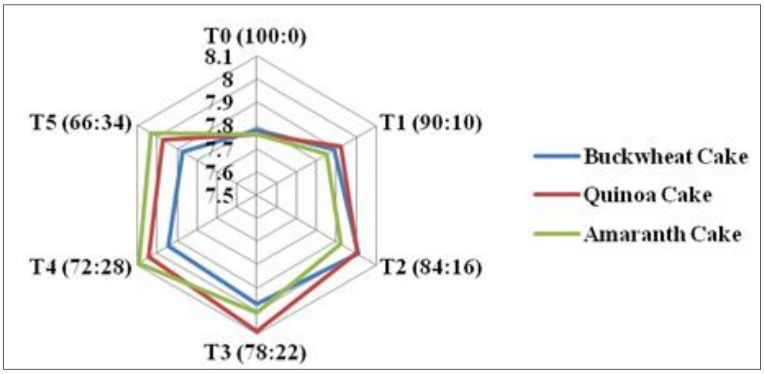
Table 1: Chemical compositions of pseudocereal flours and CP

Parameter	Pseudocereal flour (Mean ± SE)			Carrot pomace (Mean ± SE)	
	Buckwheat flour	**Quinoa flour**	**Amaranth flour**	**Fresh**	**Dried**
Moisture (%)	10.93 ± 0.59	12.02 ± 0.54	9.10 ± 0.63	87.35 ± 1.87	6.71 ± 0.63
Ash (%)	1.76 ± 0.08	2.48 ± 0.13	2.98 ± 0.12	1.56 ± 0.13	5.28 ± 0.32
Fat (%)	2.28 ±0.26	5.27 ± 0.33	6.17 ± 0.44	-	-
Crude fibre (%)	3.54 ± 0.42	3.56 ± 0.42	4.75 ± 0.50	7.12 ± 0.05	15.87 ± 0.16
Protein (%)	12.36 ± 1.10	13.69 ± 1.07	14.31 ± 1.19	-	-
Carbohydrate (%)	69.13 ± 1.08	62.98 ±1.02	62.69 ± 1.03	-	-
Total Soluble Solids	-	-	-	4.30 ± 0.30	20.00 ± 0.50
Reducing sugars (%)	0.66 ± 0.01	0.70 ± 0.01	0.64 ± 0.02	1.56 ± 0.02	11.13 ± 0.04
Total sugars (%)	2.12 ± 0.34	2.34 ± 0.32	1.91 ± 0.29	4.46 ± 0.09	17.34 ± 0.18
Total carotenoids (mg/ 100g)	-	-	-	1.93 ± 0.10	17.81 ± 0.98
Total phenols (mg GAE/ 100 g)	309.36 ± 1.88	79.58 ± 1.56	28.40 ± 0.82	7.29 ± 0.17	63.79 ± 0.95
Antioxidant activity (%)	80.60 ± 2.12	58.26 ± 1.01	13.94 ± 0.97	6.22 ± 0.67	52.28 ± 1.52

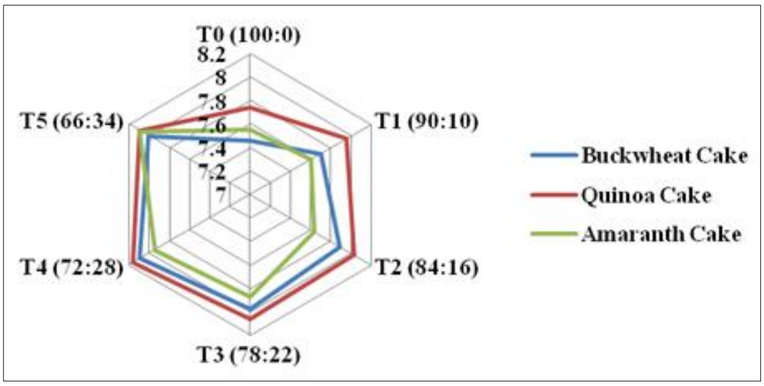
3.2 Optimization of supplementation levels of carrot pomace flour
Depending on sensory evaluation three types of cake carrying different proportions of CF and PF were selected, details of selected treatments along their sensory scores are given in Figure 2 (a, b, c and d):



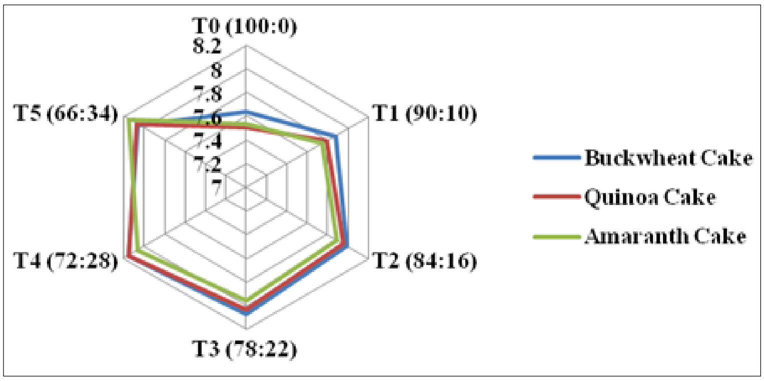
(a)



(b)



(c)



(d)

Fig 2: Sensory scores for (a) Color, (b) Texture, (c) Taste and (d) Overall acceptability of pseudocereal-based cake enriched with different levels CF

As evident from Figure 2 (d), treatments T_4 (78:28), T_4 (78:28) and T_5 (66:34) for buckwheat, quinoa and amaranth-based cake, respectively, showed the highest scores in terms of overall acceptability and hence were selected for evaluation of its nutritional content. Decrease in texture scores for the cake prepared by adding CF and *dushab*, was also noticed in study conducted by Mohtarami (2018) [18], while Afsharian, Shojaee-Aliabadi, Hosseini, Hosseini, & Mirmoghtadaie, 2021) [1] also reported higher overall acceptability scores on replacement of wheat and rice flour with CF. In an investigation carried out by Capriles *et al*. (2008) [8], it was observed that cake prepared by replacing wheat flour and corn starch up to 30% with amaranth flour slightly affected the color characteristics of the product however, overall acceptability score remained unaffected. Also, Kaur & Kaur (2017) [14] reported similar scores in terms of color, texture, flavor and overall acceptability of products prepared using 10% roasted quinoa flour.

3.3 Physical characteristics of developed products
Physical characteristics of developed products in terms of weight, volume, density, batter yield, baking loss rate, diameter, thickness and spread-ratio have been discussed in Table 2. Picture of products developed using PF and CF, along with their respective control (s) are shown in figure given below (Fig. 3).

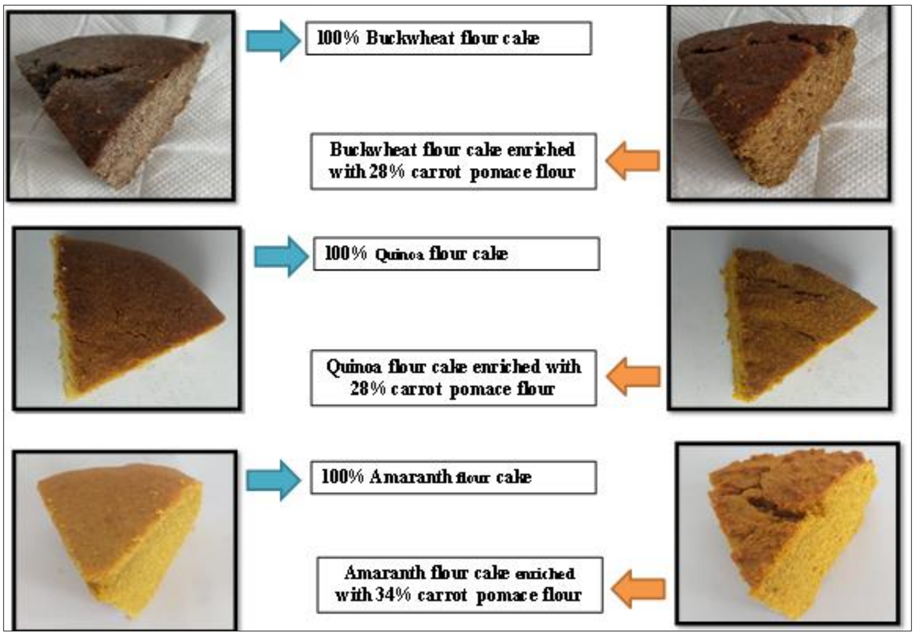


Fig 3: Pseudocereal-based cake enriched with carrot pomace flour

Table 2: Physical characteristics of selected treatments and their respective controls

Characteristics	Buckwheat-based cake (Mean ± SE)		Quinoa-based cake (Mean ± SE)		Amaranth-based cake (Mean ± SE)	
	Control	72:28	Control	72:28	Control	66:34
Weight (g)	302.16 ± 2.32	303.48 ± 2.33	300.86 ± 2.41	302.13 ± 2.43	298.39 ± 2.06	305.52 ± 1.89
Volume (cc)	865.24 ± 3.17	600.61 ± 3.11	862.87 ± 2.97	596.95 ± 2.52	864.18 ± 3.43	580.11 ± 2.75
Density (g/ cc)	0.35 ± 0.01	0.51 ± 0.01	0.35 ± 0.01	0.51 ± 0.01	0.35 ± 0.01	0.53 ± 0.01
Batter yield (%)	89.93 ± 0.12	90.87 ± 0.12	89.90 ± 0.26	90.82 ± 0.24	89.31 ± 0.10	90.89 ± 0.06
Baking loss rate (%)	10.07 ± 0.02	9.12 ± 0.01	10.11 ± 0.10	9.17 ± 0.07	10.69 ± 0.08	9.11 ± 0.07
Diameter (mm)	151.60 ± 1.02	142.00 ± 0.99	149.58 ± 1.11	141.75 ± 1.02	150.36 ± 1.23	140.22 ± 1.18
Thickness (mm)	54.37 ± 0.38	44.19 ± 0.31	52.43 ± 0.31	42.97 ± 0.34	53.52 ± 0.27	39.18 ± 0.35
Spread ratio	2.79 ± 0.02	3.21 ± 0.01	2.85 ± 0.04	3.29 ± 0.07	2.81 ± 0.02	3.59 ± 0.03

Jahanbakhshi, & Ansari (2020) [13] reported an increase in density, specific gravity and volume of the cake made by substitution of wheat flour with olive seed powder (OSP). Increase in density was however in contradiction with Majzoobi, Poor, Mesbahi, Jamalian, & Farahnaky (2017) [17], where a decrease in density of the products supplemented with CF was recorded, which in turn positively influenced the gas retention property of batter and maintenance of a uniform product structure. The increase in density of cake with the addition of CF is probably attributed to the fibre content of CP, which decrease batter aeration and disrupt the structure by liberating the trapped air or CO_2.

3.4 Nutritional composition of developed products:
As shown in Table 3, inclusion of CF into the recipe resulted in substantial increase in fibre content, total carotenoids, moisture, ash and reducing sugars content of the supplemented products. Among the three, the highest antioxidant activity and phenolic content was observed in products developed using buckwheat flour, owing to its higher content of phenols, followed by quinoa-based products. Amaranth flour being deficient in antioxidant compounds resulted in low antioxidant activity, however addition CF resulted in relatively higher values for total phenols and total carotenoids, which consequently improved the antioxidant potential of the product. Results were in compliance with the observations of Zaki, Sheir, & Sakr (2018) [25], where supplementation with 0, 10 and 15% CF increased the moisture, ash, crude fibre, beta-carotene, phenol content and antioxidant activity of wheat-based cake.

Table 3: Nutritional composition of developed products

Parameter	Buckwheat-based cake (Mean ± SE)		Quinoa-based cake (Mean ± SE)		Amaranth-based cake (Mean ± SE)	
	Control	72:28	Control	72:28	Control	66:34
Moisture (%)	22.13 ± 0.10	23.19 ± 0.08	22.83 ± 0.12	23.95 ± 0.15	20.07 ± 0.13	21.16 ± 0.14
Ash (%)	1.39 ± 0.01	2.53 ± 0.02	1.99 ± 0.02	3.06 ± 0.03	2.47 ± 0.04	3.58 ± 0.02
Fat (%)	19.11 ± 0.95	17.83 ± 1.08	20.58 ± 0.17	17.13 ± 0.22	20.87 ± 0.87	15.61 ± 0.74
Protein (%)	13.34 ± 0.68	12.26 ± 0.67	13.87 ± 0.37	12.61 ± 0.37	15.55 ± 0.64	13.89 ± 0.59
Crude fibre (%)	3.36 ± 0.04	6.68 ± 0.04	3.41 ± 0.02	6.83 ± 0.06	4.56 ± 0.04	8.40 ± 0.05
Reducing sugars (%)	0.32 ± 0.01	3.03 ± 0.04	0.39 ± 0.02	3.08 ± 0.02	0.24 ± 0.01	3.58 ± 0.03
Total sugars (%)	13.13 ± 0.18	14.05 ± 0.21	13.18 ± 0.11	14.12 ± 0.08	13.06 ± 0.20	14.23 ± 0.17
Carotenoids (mg/ 100 g)	0.57 ± 0.01	5.29 ± 0.08	0.53 ± 0.01	5.21 ± 0.03	0.47 ± 0.02	6.08 ± 0.03
Total phenols (mg GAE/ 100 g)	100.05 ± 0.82	89.19 ± 0.79	42.13 ± 0.58	34.57 ± 0.46	10.32 ± 0.09	27.41 ± 0.25
Antioxidant activity (%)	78.13 ± 0.28	70.65 ± 0.15	56.03 ± 0.32	54.55 ± 0.19	11.79 ± 0.13	21.57 ± 0.19

4. Conclusion

The replacement of pseudocereal flour with carrot pomace flour resulted in improvement of physico-chemical properties of developed products. The study was illustration of valorization of carrot juice processing waste, which was utilized for the improvement of fibre, ash and carotenoid content of cake based on buckwheat, amaranth and quinoa. In case of amaranth-based cake, supplementary increase in antioxidant and phenol content of products was also observed with the addition of CF. The supplementation levels increased by one-third in consecutive treatments till level reached to 34%. The treatment (s) exhibiting highest sensory scores for overall acceptability were selected for physico-chemical evaluation. Among all the products, those prepared from buckwheat flour showed highest phenolic content (100.05 mg GAE/100g) and antioxidant activity (78.13%), while that prepared from amaranth flour and CF (64:36) was superior in carotenoid (6.08 mg/100g) and fibre content (8.40%). Conclusively, psudocereals and CP possess the potential to fortify bakery products for development of functional foods for minimizing the risk of health conditions including diabetes, obesity, CVDs and various types of cancer, owing to their high quality protein, high fibre content and antioxidant activity.

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