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Physicochemical properties and nutritional evaluation of wheat and water chestnut composite flour

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Abstract
The present investigation was carried out to study the physiochemical properties and proximate composition of wheat and dried water chestnut composite flour. Water chestnut fruit being a rich source of starch with no gluten, its flour can be used to replace wheat flour for the production of gluten free products. Four types of composite flours were prepared using wheat and water chestnut in ratios; 80:20, 60:40, 40:60 and 20:80 (type I, type II, type III and type IV, respectively). Type I flour had significantly higher bulk density, water absorption capacity, swelling capacity as compared to other types of composite flours. Overall it was noticed that in physicochemical properties of composite flours, as the level of water chestnut flour increased, the values for these properties decreased. Among all the composite flours type I composite flour had the highest crude protein (9.4%),crude fat (3.63%) and crude fibre content (1.93%) whereas type IV composite flour had the highest ash (2.50%) and total carbohydrates content (78.00%). It found that moisture, ash and total carbohydrates in the composite flours significantly increased with the increase in the level of water chestnut flour whereas crude protein, crude fat and crude fibre were decreased significantly.

Keywords: Water chestnut flour, composite flour, physiochemical properties and proximate composition

Introduction

Water chestnut (*Trapa natans*) locally called as "Singhara" in India (Gani *et al*., 2010) belongs to the family Trapaceae, one of the free-floating plants, grown in shallow water fields, ponds or swampy lands in tropical and sub-tropical countries (Takano and Kadono, 2005) [19]. The outer pericarp is hard, making it quite difficult to peel off to obtain the internal white fruit (Tulyathan and Boondee, 2005) [20]. The fruit is used as a substitute for cereal in Indian subcontinent during fast days especially during *Navratras* and other sacred days when consumption of wheat flour is avoided.

Chestnut flour is produced from chestnut fruits which are first dried in a flow of hot air, then shelled, picked over by hand or mechanically to remove discolored chestnuts, and crushed with a stone grinding mill (Alary *et al*., 2007) [1]. Chestnut flour may be used in gluten-free flour breads due to its nutritional and health benefits. Traditionally cookies are made from wheat flour. Other cereal flours or starches can be added to give special flavors or structural properties to the final product.

Water chestnut (*Trapa bispinosa*) is the major source of starch which contains approximately 72% starch (Malik *et al.*, 2012). Water chestnut fruit being a rich source of starch with no gluten, its flour can be used to replace wheat flour for the production of gluten free products. The chestnut flour can be stored for several months at room temperature or several years at 4^0C before use and or sale (Alary *et al*., 2007) [1]. Water chestnut possesses strong antioxidant, antimicrobial and anticancer activities, which have been attributed to their bioactive components, such as polyphenols, flavonoids and alkaloids (Yu *et al*., 2013; Chiang and Ciou, 2010) [24, 4].

It has been hypothesized that the quality problems associated with using only chestnut or rice flour can be overcome by using their composition at certain level (Demirkesen *et al.*, 2010) [5]. Most snack foods being cereal based are monotonous in regard to their nutritional quality. Use of abundant supplies of sweet potato, colocasia and water chestnut in countries like India to substitute partially for wheat flour in quality products will not only reduce the excessive dependence on cereal grains but also improve the imbalance of nutrients through consumption of products based upon composite flour mixtures (Yadav *et al.*, 2014) [23]. The studies on chestnut flour are limited in literature (Demirkesen *et al.*, 2010) [5].

Composite flour is defined as a mixture of flours, starches and other ingredients intended to replace wheat flour totally or partially in bakery and pastry products. Composite flour is considered advantageous in developing countries as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour (Hugo *et al.*, 2000; Hasmadi *et al*., 2014) [8, 6]. The FAO reported that the application of composite flour in various food products would be economically advantageous if the imports of wheat could be reduced or even eliminated, and that demand for bread and pastry products could be met by the use of domestically grown products instead of wheat (Jisha *et al*., 2008) [9].

Keeping in view the above information, the present study was planned with the objective to analyze the physicochemical properties and nutritional evaluation of wheat and water chestnut composite flour.

Methodology

For the preparation of composite flour, wheat variety (WH-1105) was procured from Department of Genetics and Plant Breeding, College of Agriculture, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Well dried water chestnut and other required ingredients were purchased from the local market in a single lot.

The clean and healthy wheat grains and dried water chestnuts were used for preparation of flour. The wheat grains were ground to fine flour in a mini flourmill. The dried water chestnuts were finely ground in an electric grinder. Composite flour was prepared by mixing wheat flour (WF) with water chestnut flour (WCF) in the following ratios:

- Type I flour (80% wheat flour: 20% water chestnut flour)
- Type II flour (60% wheat flour: 40% water chestnut flour)
- Type III flour (40% wheat flour: 60% water chestnut flour)
- Type IV flour (20% wheat flour: 80% water chestnut flour)

The four types of flours were stored in air tight plastic containers for further analysis.

Physical characteristics of composite flour

Bulk density and fat absorption capacity were analyzed by the method of (AOAC, 2000) [2], Water absorption capacity was determined by the method of Wang and Kinsella (1976**)** [22] and swelling capacity was determined by the method of Robertson *et al*. (2000) [2].

Proximate composition of composite flour

Moisture content, crude protein, crude fibre, crude fat and ash were determined by employing the standard method of analysis (AOAC, 2000) [2] and total carbohydrates were analyzed by difference method.

Results and Discussion

Physico-chemical properties and nutritional evaluation of wheat and water chestnut flour

The data presented in table 1 indicated that bulk density of wheat flour was 1.4 g/ml and that of water chestnut flour 1.11 g/ml. Bulk density of water chestnut flour reported by Pejcz *et al.* (2015) [12] reported (0.87 g/ml) was lower than the value obtained in the present study. Water absorption capacity of wheat flour and water chestnut flour were 3.83 and 2.4 ml/g, respectively. Swelling capacity of wheat flour was 9.38 ml/g and that of water chestnut flour 6.45 ml/g. Water absorption capacity and swelling capacity of water chestnut flour were found higher i.e. than the values observed by Singh *et al*. (2009) [18] i.e. 0.96 ml/g, 9.72 g/ml, respectively. Wheat flour had 96.7% fat absorption capacity and water chestnut flour had 54.3%. Water absorption capacity and swelling capacity of wheat flour were higher than the values reported by earlier workers (Shafi *et al.*, 2016; Pejcz *et al.*, 2015) [15, 12]. The differences between the values might be due to the varietal differences. Fat absorption capacity of wheat flour was almost similar as reported by Shafi *et al*. (2016) [15] i.e. 94.72%. Fat absorption capacity of water chestnut flour was found lower than the values reported by Bala *et al.* (2015) [3] i.e. 62.0%. The differences in the values of physiochemical properties of water chestnut flour might be due to the different treatments used in preparation of flour. Water absorption capacity of wheat flour was higher as compared to water chestnut flour. The variations in the water absorption capacity between the flours might be due to the difference in the protein structure and the presence of hydrophilic carbohydrates. Higher fat absorption capacity of wheat flour could be attributed to low hydrophobic proteins which show superior binding of lipids. Swelling capacity is related with protein and starch content of the flour.

It was noticed from the results of the study presented in table 2. that moisture content of wheat flour was 4.3% and that of water chestnut flour 9.36%. Wheat flour was found to contain 11.08% crude protein whereas water chestnut flour had 8.03%. Crude fat content of wheat flour was 3.87% and that of water chestnut flour 2.33%. Wheat flour was found to contain 1.6% ash content while water chestnut flour had 2.76%. Crude fibre content of wheat flour and water chestnut flour was 3.83% and 0.96%, respectively. Wheat flour had 73.85% total carbohydrates and water chestnut flour 76.55%. The protein, crude fat, ash and carbohydrate content of wheat flour are in close agreement to the values mentioned by Shafi *et al*. (2016) [15] i.e. 10.94, 2.72, 1.53 and 73.59%, respectively. Protein content of wheat flour observed in present study was lower than as observed by Simovic *et al.* (2017) [16] i.e. 12.60% which could be due to different procedure employed for preparation of flours. Simovic *et al.* (2017) [16] observed lower values of crude fat in wheat flour i.e. 1.3% than the present study (2.33%). The crude fiber content of wheat flour was found higher than Shafi *et al.* (2016) [15] observed their crude fiber i.e. 0.53%, which might be due to the varietal differences.

The values observed for water chestnut flour protein, crude fat, ash and crude fibre were higher than observed by Shafi *et al*., 2016 (4.18, 0.52, 1.51 and 0.20%, respectively) might be due to the varietal differences and the different treatments used to prepare the flours. Simovic *et al.* (2017) [16] reported lower protein content in water chestnut flour (5.3%). The moisture content of water chestnut flour observed in the present study was found higher than observed by Sacchetti *et al*. (2004) [14] and Simovic *et al.* (2017) [16] i.e. 7.14 and 6.1%, respectively. The differences in moisture content might be due to difference in period of studying the flour after the processing of chestnut fruits. The ash content of water chestnut flour was higher as compared to wheat flour suggesting appreciable amount of minerals present in water chestnut.

The data presented in table 3 showed that total soluble sugars were 9.25 and 10.67 g/100g in wheat flour and water chestnut flour, respectively. Wheat flour was found to contain 7.17 g/100g reducing sugars whereas water chestnut flour had 5.23 g/100g. Non-reducing sugars were found 2.08 and 5.44 g/100g in wheat flour and water chestnut flour, respectively. Wheat flour contained 75.00 g/100g starch while water chestnut flour had 76.55 g/100g. The *in-vitro* starch digestibility of wheat flour was 64.27 mg maltose/g and that of water chestnut flour 52.00 mg maltose/g. The total soluble sugars and non-reducing sugars in water chestnut flour were higher as compared to the amount reported by Singh *et al*. (2010) [17]. Starch content of water chestnut flour was higher as compared with the content (57.1 g/100g) observed by Simovic *et al*. (2017) [16].

It was noticed from the data presented in table 4 that total phenolic content of wheat flour was 5.63 mg GAE/100g as compared to 7.13 mg GAE/100g in water chestnut flour. Vaher *et al.* (2010) [21] reported a range of 4.4 to 14.4 mg GAE/100 for wheat flour and Shafi *et al.* (2016) [15] observed 4.25 mgGAE/100g for water chestnut flour. Total Flavonoids in wheat flour were 1.87 mg RE/100g that was found lower than the range given by Li *et al*. (2014) [10] i.e. 2.4 to 3.1 mg RE/100g Total flavonoids content (1.63 mg RE/100g) of water chestnut flour was in close agreement to the values mentioned by Shafi *et al.* (2016) [15] i.e. 1.92 mg RE/100g. The antioxidant activity (DPPH) of wheat flour and water chestnut flour was 2.05 and 2.62 mg TE/100g, respectively. The antioxidant activity (DPPH) of water chestnut flour was was lower than observed by Hegazy *et al.* (2014) [7] i.e. 3.75 mg TE/100g. Polyphenolic compounds present in water chestnut can be responsible for higher antioxidant activity (DPPH).

Physico-chemical properties and nutritional evaluation of composite flours

Bulk density of different types of composite flour (type I, type II, type III and type IV) was 1.3, 1.24, 1.2 and 1.16 g/ml, respectively (Table 5). Type I flour (20% water chestnut flour) had significantly higher bulk density (1.3 g/ml) as compared to other types of composite flours. It was observed that as the level of water chestnut flour increased in composite flours, bulk density decreased significantly. Water absorption capacity of different composite flours varied from 2.0 to 3.33 ml/g (Table 5). Type I flour (20% water chestnut flour) had highest water absorption capacity (3. 33 ml/g) and type IV flour (80% water chestnut flour) the lowest (2.0 ml/g) whereas type II and type III flours had water absorption capacity i.e. 2.83 and 2.09 ml/g, respectively. It was observed that as the level of water chestnut flour increased in composite flours, water absorption capacity decreased significantly.

Swelling capacity of different composite flours i.e. type I (20% water chestnut flour), type II (40% water chestnut flour), type III (60% water chestnut flour) and type IV (80% water chestnut flour) were 9.17, 8.93, 6.25 and 6.04 ml/g, respectively (Table 5). Type I flour (9.17 ml/g) had highest swelling capacity as compared to the other types of composite flour. It was observed that with the increased level of water chestnut flour in composite flours, the swelling capacity was found to be decreased significantly. Fat absorption capacity of different composite flours (Table 5) ranged from 63.00 to 87.10%. Type I (20% water chestnut flour) composite flour had highest (87.10%) and type IV the lowest (63%) fat absorption capacity whereas type II and type III flours had 73.2 and 69.73%, respectively. It was observed that as the level of water chestnut flour increased in composite flours, the fat absorption capacity decreased significantly.

Overall it was noticed that in physicochemical properties of composite flours, type I had highest bulk density, water absorption capacity, swelling capacity and fat absorption capacity and as the level of water chestnut flour increased, the values for these properties decreased.

Proximate composition of composite flour is given in Table 6. It is evident from the table that with increase in level of water chestnut flour in the composite flours, the crude protein, crude fat and crude fibre content decreased significantly. On the other hand, moisture, ash and carbohydrates contents increased. Among all the composite flours type IV had highest (9.19%) moisture content followed by type III (8.89%), type II (7.65%) and type I (7.73%). Crude protein content of different composite flours varied from 8.05 to 9.14%; type I composite flour having the highest (9.4%) and type IV the lowest (8.05%) crude protein content. Type II and type III composite flours had 8.65 and 8.33% crude protein, respectively. Crude fat content of composite flours ranged from 2.11 to 3.63%. All four types of composite flours differed each other significantly from their fat content. Type I composite flour had highest crude fat content (3.63%) whereas type IV had the lowest (2.11%). The ash content of composite flours varied from 1.79 to 2.5%. Type IV composite flour having the highest (2.50%) amount followed by type III (2.09%), type II (2.09) and type I (1.79%).

All the four types of composite flours differed significantly among themselves for their crude fibre content. Crude fibre content of composite flours ranged from 1.33 to 1.93%; type I composite flour had the highest (1.93%) amount. Type II, type III (%) and type IV flours had 1.77%, 1.57 and 1.33%, respectively. Total carbohydrates of composite flours were ranged from 76.16 to 78.00%. The carbohydrate content of type I, type II, type III and type IV flours was 76.16%, 76.25, 76.56 and 78.00, respectively. It is depicted from the data that moisture, ash and total carbohydrates were increased with increased composition of water chestnut flour whereas crude protein, crude fat and crude fibre were found to be decreased with increased composition of water chestnut flour. The similar decreasing trend in protein content of composite flour of wheat and water chestnut flour was observed by Pejcj *et al.* (2015) [12].

There was a non-significant difference in total soluble sugars content of type I and type II composite flours whereas a significant difference existed among type II, type III and type IV composite flours (Table 7). The total soluble sugar content of type I and type II flours was 7.78 and 7.77%, respectively and that of type III and type IV was 8.50 and 10.55%, respectively. Similar trend was observed for reducing sugar content of composite flours as for total soluble sugars. The contents of reducing sugars for composite flours were 7.4, 7.06, 6.45 and 5.25 for type I, type II, type III and type IV, respectively. Non-reducing sugar content for the composite flours ranged from 0.31 to 5.3 g/100g, type IV had the highest (5.3 g/100g) content followed by type III (2.05 g/100g), type II (0.70 g/100g) and type I (0.31 g/100g). Starch content of type I, type II, type III and type IV composite flours was 76.25, 76.5, 76.17 and 77.5 g/100g, respectively. Starch content of four types of composite flour was similar and a non-significant difference existed among the flours. Similarly starch digestibility (*in vitro)* of composite flours was almost similar, the values being 56.8, 56.0, 52.8 and 52.8 mg maltose/g for type I, type II, type III and type IV, respectively.

The data depicted that total soluble sugars and non-reducing sugars content were increased with increased composition of water chestnut flour in wheat flour whereas reducing sugars were decreased with increased composition of water chestnut flour in wheat flour. Starch and starch digestibility (*in-vitro)* were found non-significantly different among composite flours.

An increasing trend in total phenols, total flavonoids and antioxidant activity (DPPH) of composite flours was observed with the increase in the level of water chestnut flour to the wheat flour (Table 8). The four types of composite flours differed significantly from each other for their total phenolic content i.e. 4.43, 5.14, 6.50 and 6.96 mg GAE/100g for type I, type II, type III and type IV, respectively. Similar trend was noticed for the flavonoids of composite flours. Type I flour had the lowest flavonoids (0.67 mg RE/100g) while type IV the highest (1.80 mg RE/100g). Total flavonoids content of type II and type III flours was 0.74 and 0.81 mg RE/100g, respectively.

The antioxidant activity (DPPH) was highest in type IV (2.73 mg TE/100g) and lowest in type I (2.16 mg TE/100g). Apparently an increasing trend was observed in antioxidant activity of composite flours but there was a non-significant difference in antioxidant activity of type II and type III flours (2.43 and 2.45 mg TE/100g, respectively).

Table 1: Physico-chemical characteristics of wheat and water chestnut flour

Physico-chemical characteristics	Wheat Flour	Water Chestnut Flour
Bulk Density (g/ml)	1.40±0.01	1.11±0.01
Water absorption capacity (ml/g)	3.83±0.09	2.40±0.10
Swelling capacity (ml/g)	9.38±0.01	6.45±0.21
Fat absorption capacity (%)	96.70±0.64	54.30±0.27

Values are mean ± SE of three independent determinations

Table 2: Proximate composition of wheat and water chestnut flour (g/100 g, on dry weight basis)

Parameters	Wheat Flour	Water Chestnut Flour
Moisture	4.30±0.09	9.36±0.23
Crude Protein	11.08±0.38	8.03±0.14
Crude Fat	3.87±0.03	2.33±0.02
Ash	1.60±0.09	2.76±0.01
Crude Fibre	3.83±0.18	0.96±0.03
Carbohydrates	73.85±1.11	76.55±0.10

Values are mean ± SE of three independent determinations

Table 3: Total soluble sugars, reducing sugars, non-reducing sugars, starch and *in vitro* starch digestibility of wheat and water chestnut flour (g/100g, on dry weight basis)

Parameters	Wheat Flour	Water Chestnut Flour
Total soluble sugars	9.25±0.25	10.67±0.03
Reducing sugars	7.17±0.14	5.23±0.25
Non-reducing sugars	2.08±0.28	5.44±0.24
Starch	75.00±0.29	77.5±0.14
In vitro starch digestibility (mg maltose/g)	64.27±5.87	52.00±0.80

Values are mean ± SE of three independent determinations

Table 4: Antioxidant activity of wheat and water chestnut flour

Antioxidant activity	Wheat Flour	Water Chestnut Flour
Total phenols (mg GAE/100g)	5.63±0.03	7.13±0.07
Total Flavonoids (mg RE/100g)	1.87±0.09	1.63±0.40
Antioxidant activity DPPH (mg TE/100g)	2.05±0.03	2.62±0.01

Values are mean ± SE of three independent determinations

GAE : Gallic Acid Equivalent RE : Rutin Equivalent

DPPH : 2,2 Diphenyl-1- Picrylhydrazyl TE : Trolox Equivalent

Table 5: Physico-chemical characteristics of composite flour

Composite flours	Bulk Density (g/ml)	Water absorption capacity (ml/g)	Swelling capacity (ml/g)	Fat absorption capacity (%)
Type I (WF:WCF :: 80:20)	1.30±0.01	3.33±0.17	9.17±0.21	87.10±0.12
Type II (WF:WCF :: 60:40)	1.24±0.01	2.83±0.167	8.93±0.19	73.20±0.16
Type III (WF:WCF :: 40:60)	1.20±0.01	2.09±0.06	6.25±0.01	69.73±0.23
Type IV (WF:WCF :: 20:80)	1.16±0.01	2.00±0.06	6.04±0.21	63.00±0.35
CD (P≤0.05)	0.02	0.35	0.51	1.04

Values are mean ± SE of three independent determinations

WF: Wheat Flour WCF: Water Chestnut Flour

Table 6: Proximate composition of composite flour (g/100 g, on dry weight basis)

Composite flours	Moisture	Crude Protein	Crude Fat	Ash	Crude Fibre	Total carbohydrates
Type I (WF:WCF :: 80:20)	7.73±0.14	9.14±0.07	3.63±0.03	1.79±0.05	1.93±0.07	76.16±0.24
Type II (WF:WCF :: 60:40)	8.31±0.01	8.65±0.02	3.51±0.02	2.01±0.06	1.77±0.03	76.25± 0.17
Type III (WF:WCF :: 40:60)	8.89±0.14	8.33±0.02	3.40±0.06	2.09±0.08	1.57±0.03	76.56±1.01
Type IV (WF:WCF :: 20:80)	9.19±0.25	8.03±0.13	2.11±0.52	2.50±0.06	1.33±0.12	78.00±0.04
CD (P≤0.05)	0.20	0.66	0.12	0.19	0.29	1.92

Values are mean ± SE of three independent determinations

WF: Wheat Flour WCF: Water Chestnut Flour

Table 7: Total soluble sugars, reducing sugars, non-reducing sugars, starch and *in-vitro* starch digestibility content of composite flours (g/100g, on dry weight basis)

Composite flours	Total Soluble Sugars	Reducing Sugars	Non-reducing sugars	Starch	*In-vitro* starch digestibility (mg maltose/g)
Type I (WF:WCF :: 80:20)	7.78±0.11	7.47±0.11	0.31±0.03	76.25±0.12	56.80±0.80
Type II (WF:WCF :: 60:40)	7.77±0.13	7.06±0.23	0.70±0.25	76.50±0.14	56.00±0.14
Type III (WF:WCF :: 40:60)	8.50±0.04	6.45±0.01	2.05±0.03	76.17±2.58	52.80±0.06
Type IV (WF:WCF :: 20:80)	10.55±0.12	5.25±0.23	5.30±0.32	77.50±0.14	52.00±0.80
CD (P≤0.05)	0.41	0.56	0.69	3.29	7.59

Values are mean ± SE of three independent determinations
WF: Wheat Flour WCF: Water Chestnut Flour

Table 8: Antioxidant activity of composite flour

Composite flours	Total phenols (mg GAE/100g)	Total Flavonoids (mg RE/100g)	Antioxidant activity DPPH (mg TE/100g)
Type I (WF:WCF:: 80:20)	4.43±0.08	0.67±0.01	2.16±0.03
Type II (WF:WCF:: 60:40)	5.14±0.24	0.74±0.01	2.43±0.03
Type III (WF:WCF:: 40:60)	6.50±0.14	0.81±0.03	2.45±0.03
Type IV (WF:WCF :: 20:80)	6.96±0.02	1.80±0.02	2.73±0.03
CD (P≤0.05)	0.38	0.52	0.09

Values are mean ± SE of three independent determinations
WF: Wheat Flour WCF: Water Chestnut Flour GAE : Gallic Acid Equivalent
RE : Rutin Equivalent DPPH : 2,2 Diphenyl-1- Picrylhydrazyl TE : Trolox Equivalent

Conclusion

The data presented in the study depicted that bulk density, water absorption capacity, swelling capacity and fat absorption capacity of wheat flour were higher as compared to water chestnut flour. Crude protein, crude fat, ash and crude fibre content of wheat flour were more than that of water chestnut flour. Water chestnut flour had higher total carbohydrates content than wheat flour. Total soluble sugars, non-reducing sugars and starch were lower in wheat flour than water chestnut flour. Wheat flour contains higher reducing sugars and *in-vitro* starch digestibility than water chestnut flour. Total phenolic content and antioxidant activity (DPPH) of wheat flour were lower as compared to water chestnut flour. Total flavonoid content of wheat flour were higher than water chestnut flour. Type I flour (20% water chestnut flour) had significantly higher bulk density, water absorption capacity, swelling capacity and fat absorption capacity as compared to other types of composite flours. Overall it was noticed that in physicochemical properties of composite flours, as the level of water chestnut flour increased, the values for these properties decreased. Among all the composite flours type I composite flour had the highest crude protein, crude fat and crude fibre content whereas type IV composite flour had the highest ash and total carbohydrates content. It found that moisture, ash and total carbohydrates in the composite flours significantly increased with the increase in the level of water chestnut flour whereas crude protein, crude fat and crude fibre were decreased significantly. There was a non-significant difference in total soluble sugars content of type I and type II composite flours whereas a significant difference existed among type II, type III and type IV composite flours. Total soluble sugars and non-reducing sugars content were found to be increased significantly with increase in the level of water chestnut flour whereas reducing sugars decreased significantly. Starch and starch digestibility (*in-vitro)* were found non-significantly different among the composite flours. An increasing trend in total phenols, total flavonoids and antioxidant activity (DPPH) of composite flours was observed with the increase in the level of water chestnut flour to the wheat flour i.e. type IV had the highest of these activities.

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