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Study of various characteristics of composite flour prepared from the blend of wheat flour and gorgon nut flour

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Abstract

The composite flour was prepared by mixing wheat flour and popped gorgon nut flour in different ratios. The composite flour was evaluated for different properties i.e. physical, functional, pasting and thermal properties. Bulk density and true density decreased wherever water absorption index and water solubility index increased with increase in percentage of popped gorgon nut flour in composite flour. In functional properties, water absorption capacity and oil absorption capacity increased but foaming capacity decreased with increase in blending proportion of popped gorgon nut flour in composite flour. Pasting temperature of composite flour ranged from 67.75°C to 67.85°C. Final viscosity of different composite flour samples ranged between 3042 to 3651 cp. Peak temperature and conclusion temperature of composite flour decreased with increase in proportion of popped gorgon nut flour.

Highlights

- Popped gorgon nut flour was mixed with wheat flour at five different levels i.e. 5%, 10%, 15%, 20% and 25% to give composite flour and different properties of composite flour were evaluated.
- There was increase in water absorption index and water solubility index with increase in the blending proportion of popped gorgon nut flour in composite flour.
- Water absorption capacity and oil absorption capacity of composite flour increased but foaming capacity decreased with increase in the level of popped gorgon nut flour.

Keywords: Gorgon nut, wheat flour, composite flour, functional properties, pasting properties

Gorgon nut is the annual floating-leaved herb mostly treated as underutilized aquatic crop but is nutritious food crop growing in diverse areas from Tropics to Frigid Zone with a great importance to wide sector of rural people. India and China are the only countries where makhana is cultivated as crop. In India, it is mainly cultivated in the states of Bihar and some parts of eastern India (Mishra *et al.* 2003). Makhana is considered as an aquatic cash crop in India (Jha *et al.* 1991). The flour produced from makhana is used as substitute of arrow root. The flour is also used to make delicious dishes like sweet meat, soups, makhana kheer and as thickener in different foods preparations. In every religion, makhana is considered as the pious and divine food item. Composite flour may be considered firstly as blend of wheat and other flour for the production of leavened or unleavened baked products or secondary wholly non-wheat blends of flour or meals for the same purpose, and for indigenous foods such as porridges and for snacks foods. A variety of wheat flour substitutions have been tried in the form of fortified flours in different bakery formulations with varying success e.g. soy or defatted soy flour, raw or defatted wheat germ, flaxseed and sunflower meal (Skrbic and Filipcev, 2008; Junqueira *et al.* 2008).

The cereal based products made from fortified flours are widely accepted and have been commercialized in many parts of the world to improve the nutritional and other quality parameters of end products. Popped gorgon nut flour offer a potential to be incorporated in wheat flour for improvement in baked products. It has been observed that protein in gorgon nut possesses balanced amino acid profile that can meet the amino acid requirements of target populations. As makhana is now increasingly accepted as a health food all over the country, it offers significant opportunities for value addition through limited investment in primary processing and packaging facilities. The popping process of the makhana improves its rheological properties as it happens by extrusion of other grains (Sanchez et al. 2008). Wheat flour and popped gorgon nut flour have a very unique attributes. The method of preparation of different bakery products from wheat flour and their combination with other flours have been reported but the reports on the utilization of popped gorgon nut flour with wheat flours or other flours are scarce. Therefore the present work was undertaken to examine different characteristics of composite flour by supplementing wheat flour with gorgon nut flour in order to identify its potential application in different food ingredients.

Materials and Methods

Gorgon nut seed and popped gorgon nut were purchased from NCRM, Darbhanga, Bihar. The seeds and popped gorgon nut were cleaned manually by removing adhering foreign matter and packed in polyethene bags for further analysis. The popped gorgon nut flour was made from popped gorgon nut kernels after reducing the moisture content of kernels to 4%. The flour collected was sieved using mesh number 85 (0.180 mm) size and packed in polythene bags and kept at ambient room temperature for further analysis. The refined wheat flour was obtained from flour mill located at Longowal, Punjab.

Preparation of blends: Blends were prepared by mixing popped gorgon nut flour and wheat flour in different combinations. The different percentage of popped gorgon nut flour at 5%, 10%, 15%, 20% and 25% levels were taken and mixed with wheat flour to give composite flour. The composite flour was stored in airtight container. All the other ingredients were obtained from laboratory and local market.

Proximate composition of wheat flour and gorgon nut flour

The moisture, ash, crude fat, crude fibre and protein content of flour were determined according to method prescribed by AOAC (2000). The total carbohydrate content was calculated by deducting the sum of the values for moisture, ash, crude fat, crude fibre and protein content from 100 (Raghuramula et al. 1983). The energy value of the sample was calculated by formula method described by Paul and Southgate (1978).

Energy value (kJ) = 17 (protein) + 38 (fat) + 17 (carbohydrate)

Starch content was estimated by anthrone reagent method suggested by Saldivar (2012).

Physical properties of flours

The procedure of Singh et al. (2008) was used to determine the bulk density (loose and packed) of the flour. True density was calculated (Deshpande and Poshadri, 2011).

$$\text{True density (g/ml)} = \frac{\text{Weight of flour sample}}{\text{Rise in toluene level}}$$

The porosity of the flour and blend was determined by the method described by Samejima et al. (1982) by the following equation:

$$\text{Porosity \%} = 1 - \frac{\text{Bulk density}}{\text{True density}}$$

A Hunter lab Color Spectrophotometer (Gretag Macthbeth, I-5, USA) was employed to measure the color values i.e. *L, a,* and *b* of the flour samples. Total colour difference (ΔE) was calculated by applying the equation:

$$\Delta E = [(L_s - L^*)^2 + (a_s - L^*)^2 + (b_s - L^{\wedge *})^2]^{(1/2)}$$

The whiteness index values which mathematically combine lightness and yellow-blue into a single term were calculated as described by Hsu et al. (2003) as follows:

$$WI = 100 - [(100 - L)^2 + a^2 + b^2]^{1/2}$$

Water absorption index (WAI) and water solubility index (WSI) of flours were determined as described by Singh et al. (2005). WSI and WAI were calculated by the equations:

$$\text{WAI (g/g)} = \frac{\text{Weight of sediment}}{\text{Weight of flour sample}}$$

$$\text{WSI (\%)} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{weight of flour sample}} \times 100$$

Functional Properties

Water absorption capacity (WAC) of flour was measured by the centrifugation method of Sosulski (1962).

$$\text{WAC}\left(\frac{g}{g}\right) = \frac{\begin{array}{c}\text{Weight of centrifuge tube after drying} - \\ \text{weight of centrifuge tube} - \text{sample wt initially taken}\end{array}}{\text{Sample weight initially taken}}$$

For the determination of oil absorption capacity (OAC), the method of Lin *et al.* (1974) was used.

$$\text{OAC}\left(\frac{g}{g}\right) = \frac{\begin{array}{c}\text{weight of centrifuge tube with sample after removing} \\ \text{oil} - (\text{centrifuge tube weight} + \text{Sample wt})\end{array}}{\text{Sample weight}}$$

The method described by Narayana and Narasinga Rao (1982) was used for the determination of foaming capacity (FC) and foam stability (FS). The FC was expressed as a percentage increase in volume:

$$\text{Foaming capacity (\%)} = \frac{\begin{array}{c}\text{Increase in volume after} \\ \text{whipping} - \text{initial volume}\end{array}}{\text{initial volume}} \times 100$$

The foam volume was recorded 1 hour after whipping to determine the foam stability (FS) as a percentage of the initial foam volume.

$$\text{Foaming stability (\%)} = \frac{\text{Volume of foam after 1 h}}{\text{Initial volume of foam}} \times 100$$

The SDS sedimentation value and alkaline water retention capacity (AWRC) of flour was estimated by method of AACC (2000).

$$\text{AWRC(\%)} = \left[\frac{\begin{array}{c}(\text{Tube, stopper, gel weight}) - \\ (\text{tube, stopper})\end{array}}{\text{Flour weight}} - 1\right]\left[\frac{86}{100 - \text{flour m.c}}\right] \times 100$$

For the estimation of least gelation concentration (LGC), the method of Sathe *et al.* (1981) was used.

Solvent retention capacity profile (SRC) was obtained according to the AACC (2000).

$$\text{SRC(\%)} = \left[\frac{\begin{array}{c}(\text{Tube, stopper, gel weight}) - \\ (\text{tube, stopper})\end{array}}{\text{Flour weight}} - 1\times\left[\frac{86}{100 - \text{flour m.c}}\right]\right] \times 100$$

Pasting properties of different flour samples were studied using Rapid Visco Analyzer (RVA Tech Master, Perten Instruments, Sweden). The thermal properties including the onset temperature (T_o), peak temperature (T_p), conclusion or end temperature (T_c) and gelatinization enthalpy (ΔH) of the popped gorgon nut flour, wheat flour and their composite flours were determined using a Differential Scanning Calorimetry (DSC-4000, Perkin Elmer, USA).

Statistical analysis

All the experiments were carried out in triplicate and results were represented as Mean±SD. The significance of differences among the values was determined using one way analysis of variance (ANOVA) followed by Duncan's multiple-range test (Duncan, 1955). STATISTICA 7 (Stat Soft, Tusla, USA) statistical software packages (p<0.05) was used to determine which means are significantly different.

Results and Discussion

Proximate composition of composite flour

In the present study, popped gorgon nut flour was substituted with wheat flour at five levels i.e. 5% ($C_{1\,(95:5)}$), 10% ($C_{2\,(90:10)}$), 15% ($C_{3\,(85:15)}$), 20% ($C_{4\,(80:20)}$) and 25% ($C_{5\,(75:25)}$) to produce food grade meal and was evaluated for its proximate composition. The composition of wheat flour and wheat flour substituted with different levels of popped gorgon nut flour is presented in Table 1. Low levels of moisture content are favorable and give relatively longer shelf life (Aryee *et al.* 2006). The popped gorgon nut composite flour samples contained moisture content ranging from 11.91% to 13.20%. It was found that moisture content decreased with increase in the percentage of popped gorgon nut flour in wheat flour. Similar results were reported by Moorthy and Viswanathan (2009) for Copra meal flour (CMF). During statistical analysis, it

Table 1: Proximate analysis of wheat flour, popped gorgon nut flour and their blends

Parameters	Wheat flour	Popped gorgon nut flour	C1 (95:5)	C2 (90 :10)	C3 (85:15)	C4 (80:20)	C5 (75:25)
Moisture (%)	13.54a±0.21	12.20b±0.20	13.20ab±0.52	12.90bc±0.29	12.60c±0.05	12.51c±0.04	11.91d±0.10
Protein (%)	11.84c±0.10	12.37b±0.46	12.13ab±0.10	11.90bc±0.17	11.94bc± 0.14	11.95bc±0.10	12.25a±0.17
Fat (%)	1.23a±0.15	0.36b±0.05	1.26a±0.15	1.16ab±0.11	1.06ac±0.05	1.0bc±0.1	0.86c±0.05
Ash (%)	0.73a±0.11	0.79a±0.11	0.86a±0.11	0.93a±0.11	0.89a±0.11	0.86a±0.30	0.66a±0.11
Crude fiber (%)	0.99a±0.10	0.83a±0.06	0.96a±0.12	0.87a±0.17	1.02a±0.21	0.96a±0.28	0.86a±0.20
Carbohydrate (%)	71.65bc±0.16	73.19a±0.63	71.56c±0.58	72.51ab±0.35	72.62a± 0.66	72.69a±0.57	73.43a±0.95
Energy Value (KJ/100 g)	1466.31b ± 3.28	1473.66c ± 4.75	1471.03b ± 9.50	1479.41ab ± 4.36	1474.42ab ± 10.08	1477.10a ± 11.22	1489.60a ± 8.14

$(C_{1\,(95:5)}) = 5\%$; $(C_{2\,(90:10)}) = 10\%$; $(C_{3\,(85:15)}) = 15\%$; $(C_{4\,(80:20)}) = 20\%$; $(C_{5\,(75:25)}) = 25\%$

Mean ±S.D. with different superscripts in a row differ significantly (p<0.05) (n=3)

Table 2: Physical properties of wheat flour, popped gorgon nut flour and their blends

Parameters	Wheat flour	Popped gorgon nut flour	C1 (95:5)	C2 (90 :10)	C3 (85:15)	C4 (80:20)	C5 (75:25)
Loose bulk density (g/ml)	0.52a±0.01	0.27b±0.01	0.49ac±0.01	0.50ab±0.02	0.47bc±0.02	0.44cd±0.00	0.42d±0.02
Packed bulk density (g/ml)	0.69a±0.01	0.39b±0.02	0.64ac±0.05	0.65ab±0.02	0.63bcd±0.02	0.62bcd±0.01	0.58d±0.02
True density (g/ml)	1.96a±0.03	1.45c±0.06	1.87a± 0.10	1.73b± 0.07	1.63bc± 0.02	1.59cd± 0.02	1.50d±0.06
Porosity (%)	73.22ab±0.85	81.35b±0.01	73.48a±1.55	70.86c±0.89	71.24bc±1.48	71.97ac± 0.63	71.96ac±0.59
Water absorption index (g/g)	4.76cd±0.12	6.48e±0.25	4.65d±0.06	4.88c±0.16	5.1b±0.02	5.33ab±0.04	5.44a±0.07
Water solubility index (%)	4.53d±0.61	15.73e±0.46	4.80d±0.40	5.73c±0.46	6.80b±0.4	7.33b±0.61	8.53a±0.23

Mean ±S.D. with different superscripts in a row differ significantly (p<0.05) (n=3)

Table 3: Colour analysis of wheat flour, popped gorgon nut flour and their blends

Parameters	Wheat flour	Popped gorgon nut flour	$C_{1\,(95:5)}$	$C_{2\,(90:10)}$	$C_{3\,(85:15)}$	$C_{4\,(80:20)}$	$C_{5\,(75:25)}$
L*	92.78a±0.36	78.12f±1.50	90.92b±0.32	89.50c±0.24	88.16d±0.23	87.35e±0.15	87.26e±0.70
a*	2.10c±0.05	3.30d±0.10	2.07c±0.06	2.12c±0.06	2.33b±0.02	2.38b±0.01	2.47a±0.05
b*	9.79a±0.05	9.14c±0.20	9.00b±0.05	8.86bc±0.08	8.75cd±0.09	8.69cd±0.21	8.58d±0.01
ΔE	11.39d±0.12	21.79e±1.37	11.62d±0.23	12.37b±0.11	13.23c±0.22	13.77a±0.18	13.97a±0.29
Whiteness index	87.65a±0.19	76.06f±1.41	87.04b±0.27	86.09c±0.14	85.09d±0.23	84.47e±0.17	84.24e±0.33

Mean ±S.D. with different superscripts in a row differ significantly (p<0.05) (n=3)

Table 4: Functional properties of wheat flour, popped gorgon nut flour and their blends

Parameters	Wheat flour	Popped gorgon nut flour	$C_{1\,(95:5)}$	$C_{2\,(90:10)}$	$C_{3\,(85:15)}$	$C_{4\,(80:20)}$	$C_{5\,(75:25)}$
Water absorption capacity (g/g)	0.46d±0.03	4.93e±0.03	0.65c±0.02	0.85b±0.01	0.88b±0.10	0.96b±0.09	1.14a±0.04
Oil absorption capacity (g/g)	1.19c±0.08	2.55d±0.11	1.20c±0.06	1.33bc±0.12	1.45ab±0.07	1.42b±0.12	1.61a±0.07
Foaming capacity (%)	32.98ac±2.99	6.90b±0.98	37.25a±3.39	33.63ab±1.43	30.74bcd±2.90	28.80bcd±2.96	27.88d±1.99
Foam stability (%)	59.61a±4.48	58.88a±7.18	61.37a±5.57	59.80a±2.56	61.87a±3.58	62.01a±4.05	62.15a±1.97
SDS-sedimentation volume (ml)	27.03d±0.55	37.33e±1.15	28.06cd±0.70	28.93c±0.30	30.76b±0.90	32.53a±0.94	32.63a±0.40
AWRC(%)	114.38f±4.35	438.93g±6.29	128.47e±2.49	159.71d±4.06	188.83c±0.98	222.80b±3.45	244.06a±1.69

Mean ±S.D. with different superscripts in a row differ significantly (p<0.05) (n=3)

Table 5: Least gelation concentration (LGC) analysis of wheat flour, popped gorgon nut flour and their blends

Concen-tration of flour (%)	Wheat flour	Popped gorgon nut flour	$C_{1\ (95:5)}$	$C_{2\ (90:10)}$	$C_{3\ (85:15)}$	$C_{4\ (80:20)}$	$C_{5\ (75:25)}$
2%	No gelation	No gelation	No gelation	No gelation	No gelation	No gelation	No gelation
4%	No gelation	Gel	No gelation	No gelation	No gelation	Gel	Gel
6%	No gelation	Firm Gel	No gelation	No gelation	Gel	Gel	Firm Gel
8%	No gelation	Firm Gel	No gelation	Gel	Gel	Firm Gel	Firm Gel
10%	Gel	V. Firm Gel	Gel	Gel	Gel	Firm Gel	Firm Gel
12%	Gel	V. Firm Gel	Gel	Gel	Firm gel	Firm Gel	Firm Gel
14%	Gel	V. Firm Gel	Firm Gel	Firm Gel	Firm Gel	V. Firm Gel	V. Firm Gel
16%	Firm Gel	V. Firm Gel	Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel
18%	V. firm gel	V. Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel
20%	V. firm gel	V. Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel	V. Firm Gel

Table 6: Solvent retention capacity (SRC) properties of wheat flour supplemented with different proportion of popped gorgon nut flour

Parameters	Wheat flour	Popped gorgon nut flour	$C_{1\ (95:5)}$	$C_{2\ (90:10)}$	$C_{3\ (85:15)}$	$C_{4\ (80:20)}$	$C_{5\ (75:25)}$
Sucrose (%)	134.82^g±1.01	471.81^f±1.42	157.86^e±2.31	188.15^d±4.60	199.76^c±2.30	221.71^b±6.06	244.39^a±2.98
Lactic acid (%)	155.50^g±3.90	463.78^f±2.77	190.89^e±2.31	212.21^d±3.32	234.18^c±3.34	286.48^b±5.49	325.42^a±3.10
Sodium carbonate (%)	134.72^g±2.44	464.76^f±10.67	173.60^e±1.87	219.75^d±3.47	240.09^c±2.18	267.58^b±1.44	295.37^a±1.66
Deionized water (%)	115.27^g±0.50	456.21^f±2.82	136.06^e±4.13	156.99^d±4.68	181.40^c±4.27	205.33^b±2.18	239.51^a±3.25

Mean ±S.D. with different superscripts in a row differ significantly ($p<0.05$) (n=3)

Table 7: Pasting characteristics of wheat flour, popped gorgon nut flour and their blends

Parameters	Wheat flour	Popped gorgon nut flour	$C_{1\ (95:5)}$	$C_{2\ (90:10)}$	$C_{3\ (85:15)}$	$C_{4\ (80:20)}$	$C_{5\ (75:25)}$
Peak viscosity (cP)	3329.00	926.00	2968.00	2881.00	2674.00	2521.00	2504.00
Trough viscosity (cP)	2039.00	531.00	1861.00	1797.00	1600.00	1545.00	1503.00
Breakdown viscosity (cP)	1290.00	395.00	1107.00	1084.00	1074.00	976.00	1001.00
Final viscosity (cP)	3976.00	1110.00	3651.00	3627.00	3176.00	3163.00	3042.00
Setback viscosity (cP)	1937.00	579.00	1790.00	1830.00	1576.00	1618.00	1539.00
Peak time (min)	6.13	1.40	6.00	5.93	5.73	5.87	5.60
Pasting temperature(°C)	67.75	–	67.75	67.80	67.85	67.70	67.80

Table 8: Differential scanning calorimetry (DSC) characteristics of wheat flour, popped gorgon nut flour and their blends

Parameters	Wheat flour	Popped gorgon nut flour	$C_{1\ (95:5)}$	$C_{2\ (90:10)}$	$C_{3\ (85:15)}$	$C_{4\ (80:20)}$	$C_{5\ (75:25)}$
Onset temperature T_o (°C)	43.99	42.12	41.37	39.49	41.19	39.50	40.29
Peak temperature T_p (°C)	74.23	67.33	73.60	71.77	70.96	69.41	67.75
End temperature T_c (°C)	94.45	93.23	91.04	94.80	96.97	93	89.26
ΔH (J/g)	99.91	82.03	142.5	93.41	60.76	102.58	90.13

was observed that moisture content of wheat flour was significantly different (p<0.05) from composite flour at all the levels from 10% to 25%. The protein content of popped gorgon nut substituted composite flour was found to have slightly higher value than wheat flour. Popped gorgon nut substituted flour at 25% ($C_{5\ (75:25)}$) had the highest protein content (12.25%). This may be due to fact that crude protein content of popped gorgon nut was slightly higher than wheat flour. The fat content of composite flour at different levels i.e. from 5% to 25% was less than wheat flour. Fat content of popped gorgon nut fortified flour varied from 1.26% to 0.86%. Reduction in fat content was observed with increase in substitution of popped gorgon nut in wheat flour. It may be due to fact that there was low fat content present in popped gorgon nut flour as compare to wheat flour. Ash is the mineral residue remaining after organic matter has been incinerated. So more is the ash content, more will be mineral content. The ash content of composite flour varied from 0.93% to 0.66%. The fiber content of composite flour varied from 0.86% to 1.02%. The fiber content of wheat flour was slightly higher than the fortified flour. As the carbohydrate content for different flour was calculated by difference method, the variation in carbohydrate content may be attributed to the differences in other constituents. Carbohydrate content gradually increased with increase in proportion of fortified flour. The similar value of carbohydrate was also reported by Islam *et al.* (2012) for refined wheat flour. Energy value plays an important role in daily life diet. It was found that energy value (kJ) increased with increase in percentage of popped gorgon nut flour and decrease in wheat flour content.

Physical properties of composite flour

The different physical properties of composite flour are presented in Table 2. Loose bulk density (LBD) is a reflection of the load the samples can carry if allowed to rest directly on one another. Loose bulk density represents the lowest attainable density with compression. The wheat flour sample had the highest loose bulk density value (0.52 g/ml). Increase in the level of popped gorgon nut flour in the wheat flour resulted in decrease in the loose bulk density value. This may be due to the influence of molecular structure, less weight and higher volume of popped gorgon nut flour. The composite flour with lower

values of loose bulk density are more desirable, as the samples would pack better during storage without losing volume, however, the values were comparable. Similar trend for loose bulk density was reported by Emmanuel *et al.* (2010) for wheat and taro flour blend at different proportions. The packed bulk density (PBD) represents the highest attainable density with compression. Increase in the level of popped gorgon nut flour in the wheat flour resulted in decrease in the packed bulk density values. These lower values indicate that popping affects the molecular integrity of the popped gorgon nut flour, thus resulting in better packing. The low density values of the formulated composite flour indicate that the volume of the blends in the package will not decrease excessively during storage or distribution. Similar trends for packed bulk density were reported by Emmanuel *et al.* (2010) for wheat and taro flour blend at different proportions. True density is the density of the solid material excluding the volume of any open and closed pores. Depending on the molecular arrangement of the material, the true density can equal the theoretical density of the material and therefore be indicative of how close the material is to a crystalline state or the proportions of a binary mixture. Popped gorgon nut flour addition resulted in decrease in true density of fortified flour. The decreasing trend in true density upon fortification of popped gorgon nut flour may be due to higher volume occupied by the popped gorgon nut flour. Vijayakumar and Mohankumar (2009) reported the true density of wheat and millet based composite flour at different proportions in the range from 1.19 to 2.5 g/ml. Porosity is a measure of the voids between the solid particles of a material. Pore space can be filled with fluids including gas or water. Air filled porosity allows gases to move within material. For gases to move throughout material, pores must be continuous. The variation in the porosity may be due to the different values of bulk density and true density of the fortified flour. Vijayakumar and Mohankumar (2009) reported the porosity of wheat and millet based composite flour at different proportions was in the range of 54.50% to 76.6%.

There was increasing trend of water absorption index upon increasing the substitution of popped gorgon nut flour in wheat flour. The formation of a porous structure in the endosperm and the capillaries formed might be responsible for the

increase in the absorption. The presence of higher level of damaged starch has been suggested as another possible reason (Mariotti *et al.* 2006). There was increasing trend of water solubility index upon increasing the substitution of popped gorgon nut flour in wheat flour. Starch had the tendency to become soluble after different cooking treatments (Jones *et al.* 2000). According to Colonna *et al.* (1984), the increase in solubility in the extruded products is attributed to dispersion of amylose and amylopectin molecules following gelatinization under mild processing conditions and to formation of low molecular weight compounds under harsher conditions may also be the valid reason of the present study.

Colour analysis

Color parameters of wheat flour and popped gorgon nut substituted composite flour in the terms of L*, a*, b*, ΔE and whiteness index are presented in Table 3. The L* value indicates the lightness, 0-100 representing dark to light. The L* in wheat flour was observed as 92.78. The L* decreased from 90.92 ($C_{1\ (95:5)}$) to 87.26 ($C_{5\ (75:25)}$) with increase in the level of popped gorgon nut flour in blend. This may be due to the lower value of L* of popped gorgon nut flour than wheat flour. During statistical analysis, it was observed that the L* of wheat flour significantly differs ($p < 0.05$) from composite flour at all the levels from 5% to 25%. a* value shows the degree of the red to green colour, with a higher positive a* value indicating more redness. The change in redness with increased in popped gorgon nut flour substitution may be due to red colour of pericarp portion adhering to popped gorgon nut flour. b* value indicates the degree of yellow to blue colour, with higher positive b* value indicating more yellowness. As the substitution increased, there was decrease in b*. The difference in the colour characteristics of different levels of substituted flour and wheat flour may be attributed to differences in colored pigments of the flours, which in turn depends on the botanical origin of the plant and also to the composition of the flour (Aboubakar *et al.* 2008).

Functional properties of composite flour

The functional properties of composite flour are presented in Table 4. Water absorption capacity (WAC) represents the ability of a product to associate with water under conditions where water is limiting (Singh, 2001). It was observed that the WAC value increased as the blending proportion increased. This may be due to the popping and grinding of popped gorgon nut, where starch structures were disrupted and crystalline regions melted as the proportion increased in wheat flour. The increase in the WAC has always been associated with the increase in the amylose leaching and solubility, and loss of starch crystalline structure (Gunaratne and Hoover, 2002). Griffith *et al.* (1998) reported an increase in the WAC, OAC and WSI in different cereals and legume after roasting. The oil absorption capacity (OAC) of flours is also important as it improves the mouth feel and retains the flavor (Kinsella, 1976). Oil retention has been attributed to the physical entrapment of the lipid by the protein (Quin and Benchat, 1975; Padmashree *et al.* 1987). OAC is the ability of the flour protein to physically bind fat by capillary attraction and it is of great importance, since fat acts as flavor retainer and also increases the mouth feel of foods, especially bread and other baked foods (Kinsella, 1976). The OAC of different levels of popped gorgon nut substituted composite flours ranged from 1.20 g/g ($C_{1\ (95:5)}$) to 1.61 g/g ($C_{5\ (75:25)}$). Griffith *et al.* (1998) also reported an increase in the WAC, OAC and WSI in different cereals and legume after roasting.

Foams are used to improve texture, consistency and appearance of foods (Akubor, 2007). Foaming capacity (FC) was calculated as percentage increase in volume of protein dispersion upon mixing. It was found that FC of composite flour gradually decreased with increase in popped gorgon nut flour. The FC of different levels of popped gorgon nut substituted composite flours ranged from 37.25% ($C_{1\ (95:5)}$) to 27.88% ($C_{5\ (75:25)}$). The foaming ability of the flour depends on the presence of the flexible protein molecules which may decrease the surface tension of water (Sathe *et al.* 1982). Graham and Phillips (1976) linked good foaming ability with flexible protein molecules, which reduced surface tension. Low foaming ability on the other hand can be related to highly order globular proteins, which resist surface denaturation. During statistical analysis, it was observed that the foaming capacity of wheat flour are significantly differ ($p < 0.05$) from 15% to 25% of substituted popped gorgon nut composite flour. Foaming stability (FS) is important since the usefulness of whipping agents depends

on their ability to maintain the foam as long as possible (Lin *et al.* 1974). Foam volume changes as a function of time for wheat and popped gorgon nut substituted composite flour. The FS of different levels of popped gorgon nut substituted composite flours ranged from 61.37% ($C_{1\ (95:5)}$) to 62.15% ($C_{5\ (75:25)}$). Since FS is governed by the ability of the film formed around the entrapped air bubbles to remain intact without draining, it follows that stable foams can only be formed by the highly surface active solutes (Cherry and McWatters, 1981). Instability of foams is indicated by drainage of liquid from the lamellae and by an increase and then rupture in the size of the bubbles (Sathe *et al.* 1982). The good foam stability of flours suggested that the native proteins that are soluble in the continuous phase (water) are very surface-active in these flours. Sedimentation value (SV) is the indirect measurement of quality and composition of gluten protein. As popped gorgon nut flour does not contain any gluten content but with the increase of blending proportion of popped gorgon nut flour with wheat flour i.e. with the decrease in wheat flour content, the sedimentation value increased to a small extent. The increase in the SV of composite flour is due to the denser particle of popped gorgon nut flour which settles as the sediment.

Alkaline water retention capacity (AWRC) is the important parameter of cookie flour. It is directly co-related with cookie diameter. Higher AWRC indicates the smaller cookie diameter. During statistical analysis it was found that AWRC of wheat flour differs significantly from all blends of composite flour (p<0.05). The least gelation concentration (LGC) which is defined as the lowest protein concentration at which gel remained in the inverted tube was used as index of gelation capacity. In 5% substitution of gorgon nut flour, LGC was observed with 10% suspension but in 25% substitution of gorgon nut flour, LGC was observed with 4% suspension onwards (Table 5). Lower is the LGC, better is the gelating ability of the protein ingredient (Akintayo *et al.* 1999) and the swelling ability of the flour is enhanced. This may be due to the change of starch structure, water absorption index and the swelling ability of popped gorgon nut flour. Emmanuel *et al.* (2010) reported the least gelation concentration of wheat flour as 10%. Defatted cereals containing high amount of protein and starch content and the gelation capacity of flour is influenced by physical competition for protein gelation and starch gelatinization (Singh, 2001).

Solvent retention capacity (SRC)

Solvent retention capacity (SRC) establishes a practical flour quality and functionality profile useful for prediction in baking performance. The lactic acid SRC is associated with glutenin characteristic, sodium carbonate SRC with levels of damaged starch and sucrose SRC with pentosan and gliadin characteristics. Water SRC is influenced by all the flour constituents. The substitution has been demonstrated to have a significant effect on the sodium carbonate, lactic acid and demineralized water retention capacities. SRC is useful for studying the contribution of the flour components to end-use quality and selection of wheat for production of flour with required functionality. Solvent retention capacity of wheat and popped gorgon nut substituted composite flour at different proportion are presented in Table 6. It was observed that with the increase of blending proportion, the sucrose SRC increased gradually. This may be due to increase in absorption and higher sucrose SRC of the popped gorgon nut flour. With the increase of blending proportions, the lactic acid SRC also increased gradually. Similarly, SRC for remaining two solvents i.e. sodium carbonate and deionized water increased with increase in proportion of composite flour. During statistical analysis, it was observed that all four types of SRC of wheat flour significantly differs (p<0.05) from 5% to 25% substituted popped gorgon nut composite flour and within the various composite flour blends.

Pasting properties

The results from the Rapid Visco Analyzer (RVA) of wheat flour and different blends are summarized in the Table 7. The rheological changes of starch can be influenced by the structural states (Hermansson and Svegmark, 1996). When starch was heated with water, it went through both physical and chemical changes such as swelling, granule rupture, crystallinity loss and amylose leaching (Lii *et al.* 1996). Pasting temperature (PT) provides an indication of the minimum temperature required to cook the flour. Pasting temperature of the wheat flour was reported as 67.75°C. Pasting temperature (PT) of composite flour ranged from 67.75°C ($C_{1\ (95:5)}$) to

67.85°C ($C_{3\ (85:15)}$). The pasting temperatures of all the composite flour are almost same in the present study. When a sufficient number of granules become swollen, a rapid increase in viscosity occurs, known as peak viscosity (PV). There was decrease in the peak viscosity as the substitution of popped gorgon nut flour increased in the composite flour. This may be due to fact that the popped gorgon nut flour had lower viscosity than the wheat flour. It has been reported that the loosely packed starch granules with high level of damaged starch easily hydrate and swell more rapidly in the presence of heat and consequently produce less peak viscosity (Mariotti *et al.* 2006). Trough viscosity is influenced by the rate of amylose exudation, granule swelling, amylose-lipid complex formation and competition between exudated amylose and remaining granules for free water. Breakdown viscosity is the measure of the ease with which the swollen granules can be disintegrated. Final viscosity indicates the ability of the material to form a viscous paste. Final viscosity is largely determined by the retro gradation of soluble amylose upon cooling (Olkku and Rha, 1978). Final viscosity (FV) of different composite blends ranged between 3651 cP ($C_{1\ (95:5)}$) to 3042 cP ($C_{5\ (75:25)}$). Setback viscosity is a measure of the syneresis of starch upon cooling of cooked starch pastes. Setback value is the recovery of the viscosity during cooling of the heated starch suspension. Lowest setback value of composite flour with 25% popped gorgon nut substitution indicates its lower tendency to retrograde. The minimum tendency to retrograde is advantage in food products such as soups and sauces, which undergo loss of viscosity and precipitation (Adebowale and Lawal, 2003).

The pasting time is the time required to become the paste. The pasting characteristics play an important role in the selection of a variety for use in the industry as a thickener, binder or for any other use. The viscosity of the gel formed during and after heating is an important factor in the selection process (Aryee *et al.* 2006). The popped gorgon nut flour had reduced RVA viscosity parameters other than pasting temperature relative to raw flour, which were influenced by molecular degradation during popping. This effect has already been observed by other authors, who attributed the decrease to early starch gelatinization (Doublier *et al.* 1986). The decrease in viscosity would therefore indicate the proportion of gelatinized starch. When the extruded or popped flour was mixed with raw flour, the popped flour fragments might be quickly dispersed in the water covering the exterior of the raw flour granules or clogging the pores on the surface of raw flour granules. Chinnaswamy *et al.* (1989) indicated that extruded flour fragments might reassociate with the uncoiled amylopectin branches, partially limiting the water absorption. Wani *et al.* (2012) reported almost same trend of the RVA profile of the wheat flour. Similar trend of RVA profiles of raw corn flour and extruded corn flour mixtures was reported by Zeng *et al.* (2011).

Thermal properties

The thermal properties like onset temperature (T_o), peak temperature (T_p), end or conclusion temperature (T_c) and ΔH of wheat flour and popped gorgon nut substituted composite flour are presented in the Table 8. As the popped gorgon nut flour increased in the blend, the onset temperature decreased. Onset temperature of different composite blends ranged between 39.49°C to 41.37°C. Granfeldt *et al.* (2000) reported a decrease in T_o and ΔH_{gel} for roasted oat and steamed barley flakes. The peak (T_p) temperature of the wheat flour was reported as 74.23°C. As the popped gorgon nut flour increased in the blend, T_p decreased. Peak temperature of different composite blends ranged between 73.60°C to 67.75°C. The popping leads to gelatinization of the starch, which agrees with the observed decrease in T_p with increase in the popped gorgon nut flour in wheat flour because starch crystallites are already melted/gelatinized in the popped flour. As the popped gorgon nut flour increased in the blend, T_c decreased. As the popped gorgon nut flour increased in the blend, ΔH provided an unclear trend. ΔH of different composite blends ranged between 60.76 J/g to 142.50 J/g. Khunae *et al.* (2007) reported increase in T_o and decrease in ΔH_{gel} of rice starches upon hydrothermal treatment.

Conclusion

The protein content of popped gorgon nut substituted composite flour was found to have higher value than wheat flour, whereas reduction in fat content was observed with increase in substitution of popped gorgon nut in wheat flour. In the physical properties, increase in the level of popped gorgon nut flour in the wheat flour resulted in decrease in the loose bulk density and

packed bulk density and true density values. There was increase in water absorption index and water solubility index with increase in the substitution of popped gorgon nut flour. In functional properties, WAC and OAC values increased but foaming capacity of composite flour decreased with increase in the blending proportion. AWRC of wheat flour differs significantly from all blends of composite flour. All four types of SRC increased with increase in proportion of composite flour. In pasting properties, there was decrease in the peak viscosity, trough viscosity and breakdown viscosity as the substitution of popped gorgon nut flour increased in the composite flour. Peak temperature of different composite blends ranged between 73.60°C to 67.75°C. As the popped gorgon nut flour increased in the blend, conclusion temperature decreased.

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