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Chemical Composition and the Effect of Salts on the Food Properties of *Triticum durum* Wholemeal Flour

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Abstract: The proximate composition, nutritionally valuable minerals and the effect of some salts (NaCl, $NaNO_3$, Na_2SO_3, Na_2CO_3, CH_3COONa) on the food properties of *Triticum durum* wholemeal flour were investigated on dry weight basis. Both the protein and carbohydrate values were high with respective values of 20.21g/100g and 65.7g/100g. Many minerals were either not detected or low but phosphorus was high with a value of 4285.71mg/100g. The lowest gelation concentration varied between 2.0 in Na_2CO_3 (0.5% w/v) and 10.0 in CH_3COONa and Na_2SO_3 (15.0% w/v). The highest value of water absorption capacity was 230.33g/100g at 2.0% w/v CH_3COONa. The oil emulsion capacity varied from 20.0g/100g at 1.0% w/v Na_2CO_3 to 80.0g/100g at 0.5%w/v NaCl. The oil emulsion stability (cm^3) was generally good in most of the salts and in all their concentrations with rate of change (cm^3/h) ranging from 1.54 to 3.75 at 24h. The foaming capacity ranged between 4.0% at 20.0% w/v CH_3COONa and 72.0% at 0.5% w/v $NaNO_3$. The foaming stability values were high in $NaN0_3$ and Na_2SO_3 while the rate of change (%min^{-1}) ranged between 0.06 and 1.67 at 1050 minutes. The protein solubility recorded two maxima under the pH and salt concentrations suggesting that the sample might be having two distinct proteins. These results indicated that *T. durum* would be potentially useful in some food formulations.

Key words: *Triticum durum,* chemical composition, food properties

Introduction

Wheat is the world's most widely cultivated plant. It is grown from the equator to 60° N and 40°S, with the greatest concentration in the warm temperate regions where the winters are cool followed by relatively dry and warm summers for ripening and with moderate rainfall between 30 and 90cm (Kochhar, 1986). In West and Central Africa wheat has apparently been grown for several centuries on small irrigated plots during the dry season in the Sudan and Sahel zones. Its importance is increasing with the development of irrigation schemes, particularly in Nigeria and also in the Lake Chad Basin in the Niger, Tchad, Cameroun Republics and in Ghana (Phillips, 1977). All wheats, whether wild or cultivated belong to the genus *Triticum* of the tribe Triticeae in the family Poaceae and subfamily Pooideae (Kochhar, 1986). Of all the wheats, bread wheat, *T. aestivum* L. is by far the most important and widely grown food crop. *T. aestivum* is an hexaploid wheat. Some varieties of *Triticum durum* Desf, used for making macaroni, have yielded well in Nigeria (Phillips, 1977). *T.durum* is a tetraploid wheat (Willis, 1973). The uses of wheat in the baking industry have been enumerated particularly in *T. aestivum* but very little is known about the composition and food properties of *T. durum*. This work aims to draw attention to the nutritional value of *T. durum,* its mineral composition and functional properties. Such information will enhance food composition tables and might lead to more nutrient applications of *T. durum*.

Materials and Methods

Collection and treatment of samples: The wheat grains were collected from the farm located in Zaria, Kaduna State, Nigeria. First of all, the shaft was removed by threshing, sorting of the grains was done to separate bad grains, stones and other non-wheat particles.
The dried whole wheat grains (without shaft) were dry-milled into flour and sieved with a screen mesh of aperture 425 microns. Sieved samples were put in McCartney bottles and kept in the laboratory deep freezer (-10°C) pending analyses.

Analysis of the samples: Moisture, total ash, ether extract and crude fibre were determined by the methods of the Association of Official Analytical Chemists (AOAC) (1990) while nitrogen was determined by the micro-Kjeldahl method described by Pearson (1976) and the percentage nitrogen was converted to crude protein by multiplying by 5.7. Carbohydrate was determined by difference. The minerals were analyzed from solutions obtained by first dry-ashing the wholemeal flour at 450°C and dissolving the ash in 0.1MHCl and transferring to 100 ml standard flask using distilled de-ionized water to make it up. Fe, Zn, Cu, Ni, Na, K, Ca, Mg, Pb and Co were determined by means of atomic absorption spectrophotometer (PYE Unicam Sp 9, Cambridge, UK)

Table 1: Chemical composition of *Triticum durum*

Parameter	Value
Moisture	7.93 ± 0.2 g/100g
Protein	20.21 ± 0.04 g/100g
Crude fat	2.79 ± 0.0 g/100g
Total ash	0.92 ± 0.04 g/100g
Crude fibre	2.46 ± 0.04 g/100g
Carbohydrate	65.70 ± 0.16 g/100g
Metabolizable energy	1564.64 kJ
Iron	4.93 ± 0.1mg/100g
Zinc	2.83 ± 0.02mg/100g
Copper	ND[a]
Nickel	ND
Sodium	19.41± 0.2mg/100g
Potassium	21.67 ± 0.01mg/100g
Calcium	14.79 ± 0.3mg/100g
Magnesium	16.69 ± 0.04mg/100g
Chromium	ND
Manganese	0.24 ± 0.01mg/100g
Lead	0.24 ± 0.02mg/100g
Cobalt	ND
Phosphorus	4285.71 ± 0.5mg/100g

[a]ND. = Not detected

while phosphorus was determined colorimetrically by Spectronic 20 (Gallenkamp, UK) using the phosphovanado molybdate method of AOAC (1990).

Functional properties: The protein solubility was examined from pH 2 - 12 by the method of Adeyeye *et al.* (1994). The sample (0.2g) was thoroughly stirred with distilled water (10ml) at room temperature, and the pH was adjusted using either 0.1M HCl or 0.1M NaOH and a supernatant was obtained whose protein content was determined by the Wiechselboven method (1946). For protein solubility in salt solutions, the salts used were NaCl, $NaN0_3$, Na_2SO_3, Na_2C0_3 and CH_3C00Na, all British Drug Houses products. The concentrations of the various salt solutions used were prepared by weighing 0.5, 1, 2, 5, 10,15 and 20g of the salts which were dissolved in 99.5, 99, 98, 95, 90, 85 and 80g of distilled, deionised water, respectively. Similar weights of 0.2g of sample were used in 10ml salt solution and the supernatant treated as above. The lowest gelation concentration, water absorption and foaming properties of the wheat wholemeal flour were determined using the methods of Sathe *et al.* (1982), replacing water with appropriate salt solutions. The emulsion capacity and stability were determined by the method described by Sathe and Salunkhe (1981). The results were means of triplicate determinations.

Statistical evaluation: The statistical calculations included: percentage value, grand mean, standard deviation, coefficient of variation percent and rate of change as appropriate.

Results and Discussion

Proximate composition: The chemical composition values of *Triticum durum* is shown in Table 1. The moisture content was low thereby affording a longer keeping quality of the flour. The crude fibre and crude fat were also low, but the crude protein and the available carbohydrate were both high. From the values of the proteins, crude fat and the available carbohydrate, the value of 1564.64kJ (1.56MJ) was obtained for the metabolizable energy. The value reported here was generally higher than the values reported for whole wheat grain by Oke and Ojofeitimi (1984) but very close to the value reported in Kilgour (1986). The protein could have been very high because of the likely application of fertilizer. The high metabolizable energy indicated that *T.durum* was a concentrated source of energy. Using a conversion factor of 0.72, the crude fat content of 2.79 was converted to total fatty acids, that is, 2.79 x 0.72 = 2.0g fatty acids (Paul and Southgate, 1978). With these chemical characteristics, *T. durum* will be useful in making pastas or alimentary pastes; macaroni, farfals, noodles and spaghetti.

Minerals: The results of the mineral analysis are also shown in Table 1. Metals not detected in the sample were Cu, Ni, Cr and Co. The following metals were of reasonable levels: Fe, Zn, Na, K, Ca, Mg and Mn. Phosphorus level was very high probably because of the use of fertilizers. Lead is not needed at any level in the body physiology and it is gratifying that its level was low in the current report. Of concern is the availability of Zn and Ca from wheat to the human body for biochemical use. The levels of phytate (287mg/100g), Phy/Zn (43.0), Ca/Phy (1.7) and [Ca][Phy]/[Zn] (0.23) have been reported in the wheat grown in Nigeria (Adeyeye *et al.,* 2000). It was therefore concluded that these minerals would be bioavailable. The consumption of animal protein will also enhance the absorption of iron in the intestine (Bender, 1992).

Functional properties: The water absorption capacity (WAC) values are shown in Table 2. The value of WAC in distilled, deionised water was 140.63% but ranged between 89.29 - 230.33 in the various salt solutions. All the coefficients of variation (CV%) were low. The best salt for the WAC property was CH_3C00Na particularly at 2.0% (w/v) and Na_2C0_3 at 2.0% (w/v) salt concentrations. The values compared favourably with WAC of 138% reported for pigeon pea flour (Oshodi and Ekperigin, 1989); 130% for soy flour, 107.1% for sunflower and 60.2% for wheat flour (Lin *et al.,* 1974); three varieties of melon by Ige *et al.* (1984) having values ranging from 200.0 -288.8%. This means that *T. durum* could be a useful replacement in viscous food formulations such as soups or baked goods.

The values for the lowest gelation concentration (LGC)

Table 2: Water absorption capacity (g/100g) of *T. durum* flour

Concentration of salts (%)[a]	Water absorption capacity							
	CH_3COONa	$NaNO_3$	Na_2SO_3	NaCl	Na_2CO_3	Mean	SD	CV%
0.0	140.63	140.63	140.63	140.63	140.63	140.63	0.0	0.0
0.5	124.66	99.58	117.20	102.27	114.64	111.67	10.5	9.4
1.0	117.70	94.36	104.50	89.29	124.13	106.0	14.9	14.0
2.0	230.33	108.53	112.27	102.71	227.15	156.20	66.3	42.5
5.0	122.07	106.54	98.09	102.04	134.89	112.73	15.4	13.6
10.0	137.83	99.75	124.91	114.59	148.72	125.16	19.2	15.3
15.0	119.45	123.22	137.0	127.93	151.29	131.78	12.7	9.7
20.0	131.35	129.47	123.75	142.82	150.75	135.63	10.9	8.1
Mean	140.50	112.76	119.78	115.29	149.03	-	-	-
SD	37.3	16.49	14.83	19.78	34.19	-	-	-
CV%	26.5	14.62	12.38	17.16	22.94	-	-	-

CV = Coefficient of variation percent, SD = Standard deviation. [a]% = w/v.

Table 3: Lowest gelation concentration (g/100g) *of T. durum* flour

Concentration of salts	Lowest gelation concentration							
	CH_3COONa	$NaNO_3$	Na_2SO_3	NaCl	Na_2CO_3	Mean	SD	CV%
0.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	0.0
0.5	4.0	6.0	6.0	4.0	2.0	4.4	1.7	38.0
1.0	4.0	6.0	6.0	6.0	4.0	5.2	1.1	21.2
2.0	8.0	6.0	4.0	2.0	4.0	4.8	2.3	47.5
5.0	4.0	6.0	6.0	4.0	6.0	5.2	1.1	47.5
10.0	10.0	4.0	10.0	4.0	6.0	6.8	3.0	44.6
15.0	8.0	4.0	6.0	2.0	4.0	4.8	2.3	47.5
20.0	10.0	8.0	8.0	4.0	6.0	7.2	2.3	31.7
Mean	7.0	6.0	6.8	4.3	5.0	-	-	-
SD	2.6	1.5	1.8	2.0	1.9	-	-	-
CV%	37.4	25.2	27.1	46.6	37.0	-	-	-

Table 4: Oil emulsion capacity (g/100g) of *T. durum* flour in various salt concentrations

Concentration of salts	Emulsion capacity							
	CH_3COONa	$NaNO_3$	Na_2SO_3	NaCl	Na_2CO_3	Mean	SD	CV%
0.0	100	100	100	100	100	100	0.0	0.0
0.5	60	60	68	80	56	64.8	9.6	14.7
1.0	60	72	56	40	20	49.6	20.1	40.6
2.0	80	40	60	60	40	56.0	16.7	29.0
5.0	60	80	60	60	60	64.0	8.9	14.0
10.0	72	56	40	72	60	60.0	13.3	22.1
15.0	80	60	60	60	20	56.0	21.9	39.1
20.0	60	40	56	56	40	50.4	9.6	19.1
Mean	71.5	63.5	62.5	66	49.5	-	-	-
SD	14.6	20.2	17.1	18.0	26.0	-	-	-
CV%	20.4	31.8	27.4	27.3	52.6	-	-	-

are shown in Table 3 for all the salts. The salt free value was 8.0% while the various salt concentration values ranged from 4.0 - 10.0% (CH_3C00Na), 4.0 - 8.0% ($NaNO_3$), 4.0 - 10.0% (Na_2S0_3), 2.0 - 6.0% (NaCl) and 2.0 - 6.0% (Na_2CO_3) showing that the best salt concentrations (w/v) were 0.5%, 1.0%, 2.0% and 15.0% in most of the salts used. Most of these values were lower or within the range of most literature values for leguminous seeds (Oshodi and Ekperigin, 1989; Ige *et al.,* 1984; Adeyeye and Aye, 1998). The variation in the gelling properties of the sample under different salt concentrations and anions might be their different

Table 5: Oil emulsion stability (cm^3) of *T. durum* flour using CH_3C00Na

Time (h) [a]	Salt concentrations (%)[b]									
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0	5	56	60	60	62	62	60	63	59.8	2.9	4.8
1	12	14	15	17	17	18	18	21	16.5	2.8	16.9
2	12	14	15	16	17	18	18	21	16.4	2.8	16.9
3	12	14	15	16	17	18	18	20	16.3	2.6	15.7
4	12	13	14	16	17	18	17	20	15.9	2.7	17.0
5	12	13	14	16	17	18	17	20	15.9	2.7	17.0
20	11	13	14	15	16	18	17	20	15.5	2.9	18.6
22	11	13	14	15	16	18	17	20	15.5	2.9	18.6
24	11	13	14	15	16	18	17	20	15.5	2.9	18.6
Mean	16.4	18.1	19.4	20.7	21.7	22.9	22.1	25	-	-	-
SD	14.5	14.2	15.2	14.8	15.1	14.7	14.2	14.3	-	-	-
CV%	88.0	78.5	78.3	71.4	69.8	64.1	64.3	57.0	-	-	-
Rate[c]	1.83	1.79	1.92	1.88	1.92	1.83	1.79	1.79	-	-	-

[a]h = hour, [b]% = w/v, [c]Rate of change per hour

Table 6: Oil emulsion stability (cm^3) of *T. durum* flour using $NaNO_3$

Time (h)	Salt concentrations (%)									
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0	55	63	70	67	67	68	62	68	65.0	4.8	7.5
1	12	28	29	26	21	22	16	20	21.8	5.9	27.0
2	12	27	28	24	20	22	15	20	31.0	5.5	26.3
3	12	27	28	24	20	21	15	20	20.9	5.5	26.4
4	12	26	28	24	20	20	15	20	20.6	5.4	26.0
5	12	26	27	23	20	20	15	20	20.4	5.1	25.0
20	11	26	27	23	20	20	15	19	20.1	5.4	26.6
22	11	26	27	23	20	20	15	19	20.1	5.4	26.6
24	11	26	27	23	20	20	15	19	20.1	5.4	26.6
Mean	16.4	30.6	32.3	28.6	25.3	25.9	20.3	25.0	-	-	-
SD	14.5	12.2	14.1	14.5	15.6	15.8	15.6	16.1	-	-	-
CV%	88.0	39.9	43.7	50.6	61.7	61.1	76.9	64.5	-	-	-
Rate	1.83	1.54	1.79	1.83	1.96	2.0	1.96	2.04	-	-	-

Table 7: Oil emulsion stability (cm^3) of *T. durum* flour using $NaNO_3$

Time (h)	Salt concentrations (%)									
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0	55	66	72	71	70	69	70	68	67.6	5.4	8.0
1	12	25	36	24	25	23	23	22	23.8	6.5	27.4
2	12	25	36	24	25	23	23	22	23.8	6.5	27.4
3	12	25	36	24	25	23	23	22	23.8	6.5	27.4
4	12	25	36	24	25	23	23	22	23.8	6.5	27.4
5	12	25	36	24	25	23	23	22	23.8	6.5	27.4
20	11	22	35	22	23	22	23	22	22.5	6.4	28.6
22	11	22	35	22	23	22	23	22	22.5	6.4	28.6
24	11	22	35	22	23	22	23	22	22.5	6.4	28.6
Mean	16.4	28.6	39.7	28.6	29.3	27.8	28.2	27.1	-	-	-
SD	14.5	14.1	12.1	16.0	15.3	15.5	15.7	15.3	-	-	-
CV%	88.0	49.4	30.6	55.9	52.1	55.7	55.5	56.6	-	-	-
Rate	1.83	1.83	1.54	2.04	1.96	1.96	1.96	1.92	-	-	-

Table 8: Oil emulsion stability (cm^3) of *T. durum* flour using NaCl

Time (h)	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0	55	73	70	66	73	71	73	67	68.5	6.1	8.9
1	12	28	25	25	26	25	26	21	23.5	5.0	21.5
2	12	27	25	24	26	25	25	21	23.1	4.8	20.8
3	12	27	25	24	25	25	25	20	22.9	4.8	21.1
4	12	27	24	24	25	24	25	20	22.6	4.7	20.9
5	12	27	24	23	25	24	25	20	22.5	4.7	20.8
20	11	26	24	23	25	24	25	20	22.3	4.9	22.0
22	11	26	24	23	24	24	24	20	22.3	4.9	22.0
24	11	26	24	23	24	24	24	20	22.3	4.9	22.0
Mean	16.4	31.9	29.4	28.3	30.3	29.6	30.2	25.4	-	-	-
SD	14.5	15.4	15.2	14.1	16.0	15.5	16.1	15.6	-	-	-
CV%	88.0	48.3	51.7	49.82	52.8	52.4	53.3	61.4	-	-	-
Rate	1.83	1.96	1.92	1.79	2.04	1.96	2.04	1.96	-	-	-

Table 9: Oil emulsion stability (cm^3) of *T. durum* flour using Na_2CO_3

Time (h)	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0	55	90	100	100	87	77	73	62	80.5	16.7	20.8
1	12	16	15	10	55	27	28	17	22.5	14.7	65.1
2	12	15	15	10	51	26	27	17	21.6	13.4	61.7
3	12	15	15	10	49	26	27	17	21.4	12.7	59.5
4	12	15	15	10	49	26	27	17	21.4	12.7	59.5
5	12	15	15	10	49	26	27	17	21.4	12.7	59.5
20	11	15	15	10	43	25	26	15	20.0	11.0	55.0
22	11	15	15	10	43	25	26	15	20.0	11.0	55.0
24	11	15	15	10	43	25	26	15	20.0	11.0	55.0
Mean	16.4	23.4	24.4	20.0	52.1	31.4	31.9	21.3	-	-	-
SD	14.5	25.0	28.3	30.0	13.7	17.1	15.4	15.3	-	-	-
CV%	88.0	106.7	115.9	150.0	26.3	54.4	48.4	71.6	-	-	-
Rate	1.83	3.13	3.54	3.75	1.83	2.17	1.96	1.96	-	-	-

Table 10: Foaming capacity (%) of *T. durum* flour in various salt concentrations

Salt	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
CH_3COONa	56.0	38.0	40.0	40.0	18.0	12.0	6.0	4.0	26.8	19.2	71.7
$NaNO_3$	56.0	72.0	58.0	54.0	52.0	26.0	36.0	36.0	48.8	14.9	30.6
Na_2SO_3	56.0	38.0	38.0	28.0	20.0	20.0	22.0	26.0	31.0	12.4	40.1
NaCl	56.0	60.0	60.0	54.0	38.0	44.0	38.0	12.0	45.3	16.2	35.8
Na_2CO_3	56.0	58.0	66.0	74.0	50.0	34.0	12.0	14.0	45.5	23.2	51.0
Mean	56.0	53.2	52.4	50.0	35.6	27.2	22.8	18.4	-	-	-
SD	0.0	14.9	12.6	17.3	16.1	12.4	14.2	12.6	-	-	-
CV%	0.0	28.0	24.1	34.5	45.2	45.5	62.2	68.5	-	-	-

effects on the relative ratios of different constituents - proteins, lipids and carbohydrates (Sathe *et al.,* 1982). The low LGC values of *T. durum* wholemeal flour might likely lead to good setting of stews prepared from it. The CV% of LGC ranged between 21.2 - 47.5 among the various salts but ranged between 25.2 - 46.6 among salt concentrations. Both range values were close showing the results were not seriously varied.

The oil emulsion capacity varied from 20.0% in Na_2CO_3 at concentrations 1.0% and 15.0% (w/v) to 80% in NaCl (0.5% w/v), $NaNO_3$ (5.0% w/v) and CH_3C00Na (2.0 and 15.0% w/v). The results in Table 4 showed that emulsion

Table 11: Foaming stability (%) of *T. durum* flour using CH_3COONa

Time (min)[a]	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0.0	100	100	100	100	100	100	100	100	100.0	0.0	0.0
30	64.3	26.3	25.0	60.0	66.7	50.0	33.3	50.0	47.0	16.8	35.7
60	35.7	5.3	20.0	40.0	33.3	33.3	33.3	0.0	28.7	12.0	41.9
90	7.1	5.3	20.0	40.0	33.3	33.3	33.3	0.0	24.6	13.9	56.6
120	7.1	5.3	15.0	10.0	33.3	33.3	33.3	0.0	19.6	13.2	67.0
150	7.1	5.3	15.0	10.0	33.3	33.3	33.3	0.0	19.6	13.2	67.0
180	7.1	5.3	15.0	10.0	33.3	33.3	33.3	0.0	19.6	13.2	67.0
1,020	7.1	0.0[b]	10.0	0.0	0.0	0.0	0.0	0.0	nd[c]	nd	nd
1,050	7.1	0.0	10.0	0.0	0.0	0.0	0.0	0.0	nd	nd	nd
Mean	27.0	21.8	25.6	38.6	47.6	45.2	42.9	75.0	-	-	-
SD	33.8	35.4	28.3	33.4	26.2	24.9	25.2	35.4	-	-	-
CV%	125.4	162.2	110.8	86.5	55.1	55.1	58.8	47.2	-	-	-
Rate	0.09	0.53	0.09	0.50	0.37	0.37	0.37	1.67	-	-	-

[a]min = minute. [b]O = Not used in calculating Mean, SD, CV% and Rate. [c]nd = Not determined.

Table 12: Foaming stability (%) of *T. durum* flour using $NaNO_3$

Time (min)	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0.0	100	100	100	100	100	100	100	100	100	0.0	0.0
30	64.3	63.9	58.6	66.7	11.5	36.5	27.8	27.8	44.6	21.3	47.7
60	35.7	16.7	58.6	66.7	11.5	23.1	16.7	27.8	35.8	23.7	66.0
90	7.1	16.7	58.6	33.3	11.5	23.1	16.7	27.8	24.4	16.2	66.7
120	7.1	16.7	41.4	14.8	11.5	23.1	16.7	27.8	19.9	10.8	54.3
150	7.1	16.7	37.9	14.8	11.5	23.1	16.7	27.8	19.5	9.8	50.5
180	7.1	16.7	37.9	14.8	11.5	23.1	16.7	27.8	19.5	9.8	50.5
1,020	7.1	16.7	37.9	14.8	11.5	23.1	16.7	27.8	19.5	9.8	50.5
1,050	7.1	16.7	37.9	14.8	11.5	23.1	16.7	27.8	19.5	9.8	50.5
Mean	27.0	31.2	49.9	37.9	21.4	33.1	27.2	35.8	-	-	-
SD	33.8	30.2	23.1	32.0	29.5	25.5	27.6	24.1	-	-	-
CV%	125.4	96.8	46.3	84.6	138.0	76.9	101.5	67.2	-	-	-
Rate	0.09	0.08	0.06	0.08	0.08	0.07	0.08	0.07	-	-	-

capacity depended mostly on salt concentration and the type of salt under consideration; NaCl, $NaNO_3$ and CH_3C00Na favoured good emulsion capacity property while Na_2CO_3 antagonized emulsion formation. The Table also showed that the CV% were highly varied at both the horizontal and the vertical levels. However the current report was better than 11.0% reported for wheat flour and 18.0% for soy flour (Lin *et al.,* 1974), hence, *T. durum* might be useful in the production of sausages, soups and cakes (Altschul and Wilcke, 1985).

The oil emulsion stability (OES) (cm^3) of *T. durum* wholemeal flour are shown in Table 5 (CH_3C00Na), 6 ($NaN0_3$), 7 (Na_2S0_3), 8 (NaCl) and 9 (Na_2C0_3) between 0.5% - 20.0% salt concentrations and stability period of 24h. The capacity of protein to aid the formation and stabilization of emulsions is important for many applications in cake batters, coffee whiteners, milks, mayonnaise, salad dressings, comminuted meats and frozen desserts (Kinsella *et al.,* 1985). The OES values were best in Na_2S0_3, Na_2C0_3 and NaCl in decreasing order respectively at various salt concentrations. The enhanced OES for some of the salt concentrations might be due to the fact that the oil binding domain had been more exposed. The change in OES as time increased (as shown in the CV%) was high in all the salts with values in CH_3COONa (57.0 - 78.5), $NaNO_3$ (39.9 - 76.9), Na_2CO_3 (30.6 - 56.6), NaCl (48.3 - 61.4) and Na_2CO_3 (26.3 - 150.0). Also the rate of change in cm^3/h was high in all the salts with values in CH_3C00Na (1.79 - 1.92), $NaNO_3$ (1.54 - 2.04), Na_2SO_3 (1.54 - 2.04), NaCl (1.79 - 2.04) and Na_2C0_3 (1.83 - 3.75). This meant that OES of the Na_2CO_3 was the least stable. The decrease in emulsion stability as time increased, might be due to increased contact leading to coalescence which thereby reduced stability (Parker, 1987). Most of the values for the rate of change here were higher than the values reported for many varieties of African yam bean seeds (AYB) whose results ranged between 0.98 - 1.60 cm^3/h

Table 13: Foaming stability (%) of *T. durum* flour using Na_2SO_3

Time (min)	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0.0	100	100	100	100	100	100	100	100	100	0.0	0.0
30	64.3	52.6	63.2	85.7	60.0	70.0	70.0	69.2	66.9	9.6	14.4
60	35.7	47.4	57.9	50.0	60.0	60.0	60.0	38.5	51.2	8.0	19.5
90	7.1	47.4	57.9	50.0	50.0	30.0	60.0	15.4	39.7	19.9	50.0
120	7.1	47.4	57.9	50.0	50.0	30.0	20.0	15.4	34.7	19.0	54.8
150	7.1	47.4	57.9	50.0	50.0	0.0	20.0	15.4	31.0	22.7	73.3
180	7.1	47.4	57.9	50.0	50.0	0.0	20.0	15.4	31.0	22.7	73.3
1,020	7.1	10.5	0.0	28.6	0.0	0.0	20.0	0.0	8.3	10.9	131.5
1,050	7.1	10.5	0.0	0.0	0.0	0.0	20.0	0.0	4.7	7.4	157.3
Mean	27.0	45.6	64.7	58.0	60	58.0	43.3	38.5	-	-	-
SD	33.8	26.2	15.7	23.1	18.3	29.5	30.0	33.8	-	-	-
CV%	125.4	57.4	24.3	39.7	30.4	50.9	69.2	87.9	-	-	-
Rate	0.09	0.09	0.23	0.07	0.28	0.58	0.08	0.47	-	-	-

Table 14: Foaming stability (%) of *T. durum* flour using NaCl

Time (min)	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0.0	100	100	100	100	100	100	100	100	100	0.0	0.0
30	64.3	70.0	66.7	79.3	21.1	18.2	21.1	12.5	44.1	28.2	63.9
60	35.7	70.0	66.7	79.3	21.1	32.6	15.8	12.5	43.1	29.6	68.7
90	7.1	70.0	66.7	29.6	21.1	30.6	15.8	6.3	28.8	25.6	88.8
120	7.1	26.7	23.3	29.6	21.1	13.6	15.8	6.3	17.9	8.7	48.4
150	7.1	26.7	23.3	25.9	15.8	13.6	15.8	6.3	16.8	2.9	17.4
180	7.1	23.3	20.0	25.9	15.8	13.6	15.8	6.3	16.0	7.1	44.1
1,020	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	nd	nd	nd
1.050	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	nd	nd	nd
Mean	27.0	55.2	52.4	52.8	30.8	26.6	28.6	21.4	-	-	-
SD	33.8	29.7	30.6	32.0	30.6	32.4	31.6	34.8	-	-	-
CV%	125.4	53.8	58.4	60.6	99.3	121.7	110.5	162.3	-	-	-
Rate	0.09	0.43	0.44	0.41	0.47	0.48	0.47	0.52	-	-	-

(Adeyeye and Aye, 1998). This meant that *T. durum* might not be a good oil emulsion stabilizer when compared to AYB.

The oil absorption capacity (OAC) of *T. durum* was 72.44% which was lower than the values obtained for wheat and soy flours (84.2%) and (84.4%) respectively (Lin *et al.,* 1974). Contrary to the absorption of water, *T. durum* flour bound less to oil than water. In this regard, structurally, the *T. durum* wholemeal flour could be more hydrophilic in nature. The OAC obtained for *T. durum* was much lower than the values obtained for many leguminous seeds (Adeyeye and Aye, 1998; Oshodi and Adeladun, 1993; Fagbemi and Oshodi, 1991). OAC is important since oil acts as a flavour retainer and increases the mouth feel of foods (Kinsella, 1976). This meant that *T. durum* flour may not be a good flavour retainer compared with those samples cited from literature.

The foaming capacity (FC) of *T. durum* under various salts and salt concentrations are shown in Table 10. High foaming capacity variation existed between salts and within salt concentrations as depicted by the CV%. The values of FC ranged from 4.0 - 38.0% (CH_3COONa), 26.0 - 72.0% ($NaNO_3$), 20.0 - 38.0% (Na_2SO_3), 12.0 - 60.0% (NaCl) and 12.0 - 74.0% (Na_2CO_3). While the highest FC was reported for Na_2CO_3 at 2.0% (w/v) salt concentration, lowest FC was recorded for CH_3COONa at 20.0% (w/v) salt concentration. Some of the FC values were better than the values earlier reported like the hulled seed flours of AYB (39.91 - 55.43%) and the dehulled AYB seeds (21.34-48.44%) (Adeyeye and Aye, 1998) but much lower than 600.0% reported for sunflower (Lin *et al,* 1974). The high foaming capacities of *T. durum* flour will enhance its functionality in its uses for the production of cakes (Johnson *et al.*, 1979; Lee *et al.,* 1993) and whipping toppings where foaming is an important property (Kinsella, 1979).

The foaming stability (FS) values are shown in Tables

Table 15: Foaming stability (%) of *T. durum* flour using Na_2CO_3

Time (min)	Salt concentrations (%)										
	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0	Mean	SD	CV%
0.0	100	100	100	100	100	100	100	100	100	0.0	0.0
30	64.3	24.1	57.6	56.8	48.0	47.1	66.7	57.1	52.7	13.4	25.5
60	35.7	24.1	30.3	32.4	32.0	23.5	66.7	28.6	34.2	13.8	40.3
90	7.1	17.2	24.2	24.3	20.0	23.5	66.7	28.6	26.5	17.5	66.1
120	7.1	17.2	21.2	16.2	20.0	23.5	66.7	14.3	23.3	18.2	78.3
150	7.1	17.2	21.2	16.2	16.0	11.8	50.0	14.3	19.2	13.1	68.1
180	7.1	17.2	15.2	16.2	16.0	11.8	50.0	14.3	18.5	13.1	71.1
1,020	7.1	13.8	15.2	16.2	16.0	11.8	50.0	14.3	18.0	13.2	73.4
1,050	7.1	13.8	15.2	16.2	16.0	11.8	50.0	14.3	18.0	13.2	73.4
Mean	27.0	27.2	33.3	32.7	31.6	29.4	63.0	31.8	-	-	-
SD	33.8	27.6	28.3	28.6	27.8	28.8	16.2	29.3	-	-	-
CV%	125.4	101.3	84.9	87.3	88.2	98.0	25.7	92.2	-	-	-
Rate	0.09	0.08	0.08	0.08	0.08	0.08	0.05	0.08	-	-	-

11 (CH_3C00Na), 12 ($NaNO_3$), 13 (Na_2SO_3), 14 (NaCl) and 15 (Na_2CO_3). The order of decreasing foaming stability among the salts were Na_2CO_3 (rate = 0.05 -0.08% min^{-1}) > $NaNO_3$ (rate = 0.06 -0.08% min^{-1}) > Na_2SO_3 (rate = 0.07 - 0.47% min^{-1}) > NaCl (rate = 0.41 - 0.52% min^{-1}) and CH_3C00Na (rate = 0.09 - 1.67% min^{-1}). The best Na_2CO_3 concentration was 15.0% (w/v), 1.0% (w/v) in $NaNO_3$, 15.0% (w/v) in Na_2SO_3, 2.0% (w/v) in NaCl and 1.0% (w/v) in CH_3COONa. The values of FS% at the end of two hours period had been reported in literature for some legumes. The FS% for hulled AYB seeds ranged between 43.3 - 42.5 (Adeyeye and Aye, 1998), soy flour (14.6%) and sunflower flour (9.0%) (Lin *et al.,* 1974) and pigeon pea (20.0%) (Oshodi and Ekperigin, 1989), most of our results were greater than these quoted values: however our values were lower than 91.0% reported for raw cowpea flour (Padmashree *et al.,* 1987) for the same time interval. Foam stability is important since success of a whipping agent depends on its ability to maintain the whip as long as possible. As seen in Tables 11 - 15, the type of salts and their concentrations have a lot of influence on the foam stability of *T. durum.*
The results of the pH effects on the protein solubility of *T. durum* are depicted in Fig. 1. The sample flour showed maximum protein solubility in both acidic and basic regions of the pH. The isoelectric point (pI) was pH 7 at 6.0% protein solubility. Highest solubility at acidic region was 10.0% (pH 5) while it was 8.0% (pH 9-10) at basic region. Although the solubility values were low, the fact that the sample was soluble at both acid and basic regions meant that the *T. durum* flour might be useful in the formulation of acid foods such as protein rich carbonated beverages and milk analogue products (Kinsella, 1979; Cherry, 1981). The minimum solubilities (pI) were recorded for various salts at various concentrations, viz: $NaNO_3$, 5.6% (0.5% w/v); Na_2SO_3, 6.0% (1.0% w/v); NaCl, 4.0% (0.5%, 2.0%,20% w/v), Na_2C0_3, 1.2% (15% w/v) and CH_3COONa, 0.40% (0.5%, 1.0% w/v). For the maximum solubility, values were also as varied as the above, viz: $NaNO_3$, 23.9% (15.0% w/v); Na_2SO_3, 35.9% (5.0% w/v); NaCl, 35.9% (1.0% w/v); Na_2CO_3, 16.0% (0.5% w/v) and CH_3COONa, 12.0% (20.0% w/v). The lyotropic series here could therefore be in the order: SO_3^{2-} > Cl^- > NO_3^- > CO_3^{2-} >CH_3COO^- (Fig. 2). Shen (1981) studied the effect of various neutral salts on the solubility of soy proteins.
Globulins solubility is dependent upon salt concentration. The effect of salts in increasing the solubility of globulins is called the "salting - in" effect. The solubility is a function of the ionic strength, which is readily calculated from the molar concentrations of the ions and their charge, using the expression

$$\mu = \frac{1}{2} \sum mZ^2$$

where μ is the ionic strength, m the molarity and Z the charge of the ion, the ∑ denotes that the mZ^2 terms are added for each of the ions (White *et al.,* 1973) (see Table 16). The Table shows that the sample was generally more soluble between 0.5% -5% (w/v) of salt concentration.
The solubility in most of the salt solutions was better than in pH. However, there was general decrease in solubility for most of the salts particularly at concentrations 15.0 - 20.0% (w/v), this might be due to sample denaturation. This is also explained by the "salting-out" phenomenon where proteins are precipitated from aqueous solution by high concentrations of neutral salts. Di - and trivalent ions are more effective than univalent ions. This is seen in the results of Na_2S0_3 and Na_2C0_3. However, in the case of CH_3COO^-, which might be a water-structure-enhancing ion here (Kinsella *et al.,* 1985), the solubility was low in virtually all the solutions indicating that CH_3COO^- has only a positive effect on the hydrophobic interactions. As shown in pH effects and the salts effects, each graph showed at least two distinct peaks showing that *T. durum* might be having two distinct proteins.

Table 16: Various salts concentration (percentage and molarity) and ionic strength (μ)

Salt	Percentage concentration	Molarity	Ionic strength
NaCl	0.5	8.2×10^{-4}	8.5×10^{-4}
NaCl	1.0	1.7×10^{-3}	1.7×10^{-3}
NaCl	2.0	3.4×10^{-3}	3.4×10^{-3}
NaCl	5.0	8.1×10^{-3}	8.1×10^{-3}
NaCl	10.0	1.5×10^{-2}	1.5×10^{-2}
NaCl	15.0	2.2×10^{-2}	2.2×10^{-2}
NaCl	20.0	2.7×10^{-2}	2.7×10^{-2}
$NaN0_3$	0.5	5.9×10^{-4}	5.9×10^{-4}
$NaN0_3$	1.0	1.2×10^{-3}	1.2×10^{-3}
$NaN0_3$	2.0	2.3×10^{-3}	2.3×10^{-3}
$NaN0_3$	5.0	5.6×10^{-3}	5.6×10^{-3}
$NaN0_3$	10.0	1.1×10^{-2}	1.1×10^{-2}
$NaN0_3$	15.0	1.5×10^{-2}	1.5×10^{-2}
$NaN0_3$	20.0	1.9×10^{-2}	1.9×10^{-2}
Na_2S0_3	0.5	3.9×10^{-4}	1.2×10^{-3}
Na_2S0_3	1.0	7.9×10^{-4}	2.4×10^{-3}
Na_2S0_3	2.0	1.6×10^{-3}	4.8×10^{-3}
Na_2S0_3	5.0	3.8×10^{-3}	1.14×10^{-2}
Na_2S0_3	10.0	7.1×10^{-3}	2.14×10^{-2}
Na_2S0_3	15.0	1.01×10^{-2}	3.03×10^{-2}
Na_2S0_3	20.0	1.3×10^{-2}	3.9×10^{-2}
Na_2CO_3	0.5	4.7×10^{-4}	1.41×10^{-3}
Na_2CO_3	1.0	9.3×10^{-4}	2.8×10^{-3}
Na_2CO_3	2.0	1.8×10^{-3}	5.4×10^{-3}
Na_2CO_3	5.0	4.5×10^{-3}	1.35×10^{-2}
Na_2CO_3	10.0	8.5×10^{-3}	2.6×10^{-2}
Na_2CO_3	15.0	1.2×10^{-2}	3.6×10^{-2}
Na_2CO_3	20.0	1.51×10^{-2}	4.5×10^{-1}
CH_3C00Na	0.5	6.1×10^{-4}	6.1×10^{-4}
CH_3C00Na	1.0	1.2×10^{-3}	1.2×10^{-3}
CH_3C00Na	2.0	2.4×10^{-3}	2.4×10^{-3}
CH_3C00Na	5.0	5.8×10^{-3}	5.8×10^{-3}
CH_3C00Na	10.0	1.1×10^{-2}	1.1×10^{-2}
CH_3C00Na	15.0	1.6×10^{-2}	1.6×10^{-2}
CH_3C00Na	20.0	1.95×10^{-2}	1.95×10^{-2}

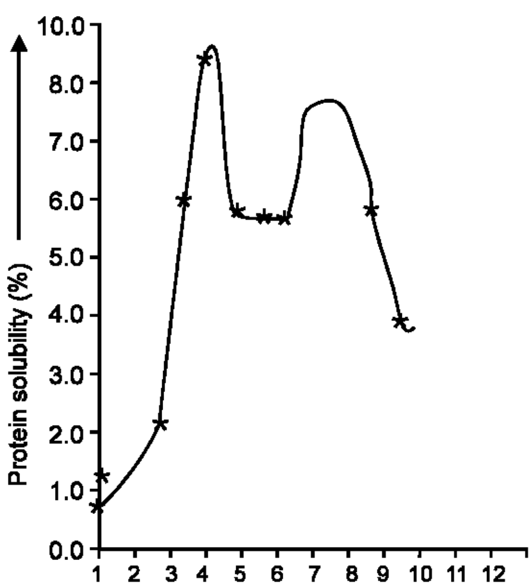

Fig. 1: Protein solubility of Triticum durum as a functionof pH --------->

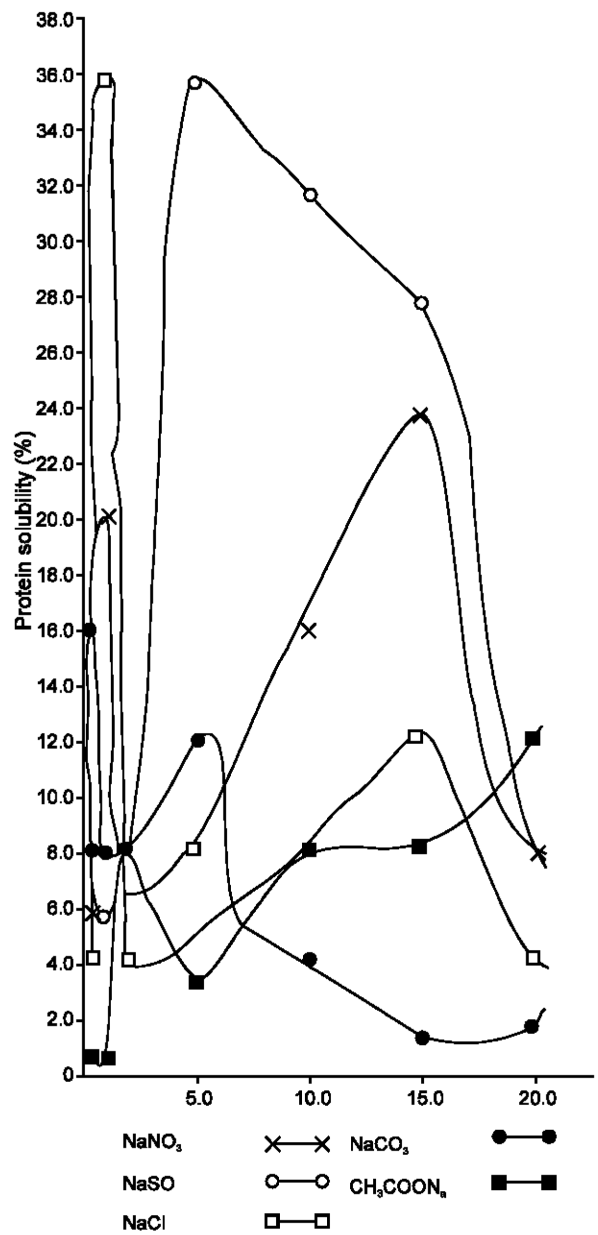

Fig. 2: Protein solubility of *Triticum aestivum* as a function of salts concentrations (%)

Conclusion: *Triticum durum* is a good source of proteins and carbohydrates with a good value of metabolizable energy and average mineral supply having a good Na-K ratio. The following functional properties were also favourable: water absorption capacity, lowest gelation concentration, oil emulsion capacity and stability, foaming capacity and stability, oil absorption capacity and protein solubility, making it potentially useful in many food formulations.

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