World Journal of Applied Chemistry
2016; 1(1): 30-37
http://www.sciencepublishinggroup.com/j/wjac
doi: 10.11648/j.wjac.20160101.16

Review Article

African Cereals and Non-African Cereals: A Comparative Review of Their Nutritional Composition

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To cite this article:

Edward-Ekpu Douglas Uwagbale, Audu Stephen Saratu, Odiba Victor Akagwu, Okopi Ochaba Stephen, Affiku Manyi Lilian. African Cereals and Non-African Cereals: A Comparative Review of Their Nutritional Composition. *World Journal of Applied Chemistry.* Vol. 1, No. 1, 2016, pp. 30-37. doi: 10.11648/j.wjac.20160101.16

Received: October 7, 2016; **Accepted**: October 28, 2016; **Published**: January 7, 2017

Abstract: Cereals were classified according to origin and major producing area, and their nutritional composition compared. Data from researches on nutritional composition of cereals were compiled, categorised and compared. African Cereals (AC) were found to be richer than NAC in all the amino acids covered in this study except in lysine and tyrosine. AC have lower fat, higher carbohydrate and ash contents though acha and oat were observed to have the highest ash contents in this study. Among the cereals in this study, acha, was observed to be the richest in sulphur amino acids, aromatic amino acid, threomine and tryptophan; acha and finger millet were observed to be exceptionally the richest in calcium while teff has the highest magnesium and zinc content. Non-African Cereals (NAC) were found to be richer than AC in protein and fibre content though pearl millet was observed to have comparable protein content. NAC were found to be richer than AC in manganese, phosphorus, potassium and sodium with wheat having the highest phosphorus and sodium contents. The copper content of pearl millet and the manganese content of wheat were observed to be unhealthily higher than their RDAs. B-vitamins were observed to be higher in NAC while barley and oat were observed to be better sources of thiamine and riboflavin among the cereals studied.

Keywords: Cereals, African Cereals, Non-African Cereals, Proximate Composition, Mineral Composition, Amino Acid Composition, Vitamins, Acha

1. African Cereals and Non-African Cereals

Cereals are the most important sources of food [1]. Cereals are staple foods, providing a major source of carbohydrate, protein, B vitamins and minerals for the world's population. Cereal based foods represent the bulk of all foods consumed and their contribution to human nutrition and health should be considered cumulative, immediate and significant [2]. The most extensively cultivated cereals are wheat (*Triticum aestivum/durum*), barley (*Hordeum vulgare*), oat (*Avena sativa*), rye (*Secale cereale*), rice (*Oryza sativa/glaberrima* Steud.), maize (*Zea mays* L), sorghums (*Sorghum bicolor* L. Moench) and different kinds of millet. Sorghum and millets are the only grains that originated from Africa. With the exception of maize, which is native to the Americas (the Western Hemisphere), nearly all true cereal grains originated in Europe and Asia in [3-6]. Africa is the centre of origin and still today the major producing area for sorghum, pearl millet (*pennisetum glaucum* (L) R.), finger millet (*Eleucine coracana* L. Gaertn.), teff (*Eragrotis tef* (Zuccagni)), acha (*Digitaria exilis* Kipp. Stapf and *Digitaria iburua* Stapf). These traditional African cereals have been called "Orphan Crops" or "Lost Crops", and less is known

about sorghum and millets compared to maize, wheat, rye, barley or oat [5]. Sorghum and millet are particularly major contributors of overall calorie intake in semi-arid parts of Africa where they are majorly staple food. These crops are important in certain locations in Africa, where major cereals cannot be relied on to provide sustainable yields. The traditional foods from sorghum and millets are breads, porridges, beverages, snacks food and drinks [7]. Sorghum and millet contribute up to 85% of daily caloric intake in Burkina Faso and Niger [8]. According to Hulse *et al*. [9] and Saldivar [10], four major millet species are produced significantly in Africa: pearl millet (the most widely grown in 76% area), finger millet (19% area), tef (9%) and acha (4%). It is documented that traditional African cereals are not well researched [11] and African grains quality standard are not well developed because of lack of attention by research and extension services [12] thus they have very low yields [13]. Sorghum and millets are grown in harsh environment where other crops grow or yield poorly. They are grown with limited water resources and usually without application of any fertilizer or other inputs [7].

Based on the classification of cereals according to origin and major producing area, sorghum, pearl millet, finger millet, teff, and acha can be classified as African Cereals (AC). Cereals that originated from and are majorly produces outside Africa can be classified as Non-African Cereals (NAC). Some NAC however have become major staple food in many African countries. The important cereals of non-African origin are maize, wheat, Asian rice (common rice), oat, barley and rye with maize, rice and wheat consumed mainly as staple food globally. Most of the quantity of wheat produced is for human consumption [2]. Maize is a cheap form of starch and is a major energy source for animal feed [14]. Rye is used to make crispbread and alcohol, and it is used also as animal feed [15]. Oats have mainly been grown for animal feed. Barley is grown for animal feed, especially for pigs; for malting and brewing in the manufacture of beer; and for distilling in whisky manufacture [2]. The composition of nutrients in these cereals can vary considerably between regions within a country as well as between countries. Such differences can be caused by variation in temperature, rainfall and access to water, use of fertilizer, nutrient content of the soil, variant, etc. [16]. This review is aimed at providing at-a-glance comparison of AC and NAC; highlighting some nutritional advantages of African cereals as an alternative to maize, wheat, barley etc. in Africa and as an option in solving food security problem in Africa. This review also highlighted some nutritional inferiorities of AC to NAC and therefore nutritional qualities of AC that require improvement.

2. Nutritional Composition of the Cereals

2.1. Proximate Composition

The proximate compositions reported in different research papers (3 papers each) of the cereals under investigation were analysed and compared with their respective Recommended Dietary Allowance (RDA). The mean moisture content of AC ranged from 7.0% calculated for finger millet to 12% calculated for pearl millet. The mean moisture content of NAC ranged from 9.3% (maize) to 14.4% (rye). This showed low moisture contents for AC. This low moisture content may be connected to the fact that AC are grown and can grow with limited water [7]. NAC were observed to be richer in protein content. The protein content of AC ranged from 8.4% (finger millet) to 11.4% (pearl millet) whereas protein content of NAC ranged from 10.4% (maize and rye) to 13.9% (barley). Barley and oat have %RDAs above 22% reported for lean beef [58]. Wheat (21% RDA) is a little below, while pearl millet (20% RDA) is the only AC with %RDA close to that of lean beef. Apart from maize having 74.3% of carbohydrate, all the other NAC showed less carbohydrate content than teff (73%) which has a value only higher than that of pearl millet (69%) in the AC class. The %RDAs of Carbohydrate in AC ranged from 53-63% while that of NAC ranged from 37-57%. Oat (5.3%) and maize (4.2%) of fat are the highest values observed for NAC, higher than the two highest values of AC as observed in Pearl millet at 4.8% and sorghum at 2.7%. Finger millet, wheat and rye contain the lowest amount of fat at 1.4%, 1.5% and 1.6% respectively, and Finger millet, teff, wheat, barley and rye have %RDA of 1%. Whole cereal grains are considered a rich source of fibre as fibres tend to be concentrated in the outer bran and aleurone layers of the grain [60]. The mean fibre content of the cereals of NAC ranges from 4.1% (barley) to 8.1% (oat) showing a higher fibre content for NAC. Pearl millet at 4.4% and finger millet at 3.4% of fibre are the highest values observed for AC. Acha and sorghum showed very low fibre contents (1% RDA). Ash content of AC ranges from 1.6% to 2.9%. Ash content of NAC has a similar range of 1.6% to 2.8%. Acha and oat have the highest ash content in this study.

Table 1. *Mean Proximate Composition (g/100g) and Recommended Dietary Allowance (RDA)*.*

	African Cereals					**Non-African Cereals**				
	Pearl[a] Millet	**Finger[b] Millet**	**Acha[c]**	**Teff[d]**	**Sorgh.[e]**	**Wheat[f]**	**Maize[g]**	**Barley[h]**	**Oat[i]**	**Rye[j]**
Moist	12.0	7.0	10.9	10.8	10.6	12.0	9.3	10.3	13.0	14.4
Prot.	11.4 (20%)	8.5 (15%)	8.4 (15%)	10.2 (18%)	9.6 (17%)	11.8 (21%)	10.4 (19%)	13.9 (25%)	13.5 (24%)	10.4 (19%)
Carb.	69.0 (53%)	77.9 (60%)	75.2 (58%)	73.0 (56%)	81.6 (63%)	70.1 (54%)	74.3 (57%)	52.9 (41%)	48.6 (37%)	63.8 (49%)
Fat	4.8 (19%)	1.4 (1%)	2.4 (10%)	2.1 (1%)	2.7 (11%)	1.5 (1%)	4.2 (17%)	2.2 (1%)	5.3 (21%)	1.6 (1%)
Fibre	4.4 (16%)	3.4 (12%)	2.6 (1%)	3.2 (11%)	2 (1%)	5.2 (19%)	6.6 (24%)	4.1 (15%)	8.1 (29%)	5.5 (20%)
Ash	2.1	2.6	2.9	2.5	1.6	1.6	2.0	2.2	2.8	1.7

Sources: *[17], [a][5, 18-19], [b][18, 28-29], [c][18, 23-24], [d][5, 18, 32], [e][18-19, 36], [f][5, 18-19], [g][41-43], [h][39, 45-46], [i][46, 49-50], [j][55-57]

2.2. Mineral Composition

Twenty-two (22) mineral elements are required in the body [61]. Some are required in large amounts, but iron, Manganese, Zinc and Copper are required in trace amounts because higher concentrations can be harmful [62-63]. The mineral compositions reported in different research papers (3 papers each) of the cereals under investigation were analysed and compared with their respective RDA. Calcium content of finger millet (275mg/100g) and teff (168.1mg/100g) are far higher than that of all the cereals in this study. While the other cereals have %RDA less than 5%, finger millet and teff have %RDAs of 21% and 13% respectively. Among the NAC, barley has the highest calcium content (66.7mg/100g). Copper content as observed in both classes of cereals except in pearl millet ranged from 0.3-2.9mg/100g. Apart from sorghum (1.4mg/100g), teff (2.9mg/100g) and wheat (1.1mg/100g) with values above 1mg/100g all other cereals showed values that are less than 1mg/100g. Pearl millet has an exceptionally high value of 9.8mg/100g. Very high %RDAs of 1089%, 322% and 156% were observed for pearl millet, teff and sorghum respectively. AC showed higher iron content with sorghum (25mg/100g) and pearl millet (8.5mg/100g) having the highest values. 5.3 mg/100g recorded for both barley and oat is the highest value under NAC category. While the %RDAs of iron in NAC ranged from 35-66%, high %RDAs were observed for pearl millet (106%), teff (171%), and sorghum (313%). In the case of manganese, the reverse is the case. NAC gave higher values with wheat (19.4 mg/100g) and oat (4.2 mg/100g) having the highest values. The manganese value (36.0 mg/100g) reported by Obilana and Manyasa [18] for wheat appears to be too high compared to 2.8 mg/100g reported by Kowieska *et al* [39]. The manganese content of wheat (19.4 mg/100g) gave a very high %RDA of 843%. Values of magnesium, phosphorus and potassium of both classes of cereals are all above 100mg/100g except for magnesium value of acha (87.3mg/100g) and maize (75.3mg/100g). Pearl millet (153.3mg/100g), teff (175mg/100g) and sorghum (174.mg/100g) are all richer in magnesium than all the cereals in the NAC class. %RDAs of manganese in AC ranged from 21-42% and that of NAC ranged from 18-36%. Wheat, barley and rye all have mean phosphorus values above 325mg/100g as calculated for oat while pearl millet, teff and sorghum have values above 350mg/100g. %RDAs of phosphorus in AC ranged from 31-59% and that of NAC ranged from 31-63%. Potassium content of AC ranged from 268.5-440.0 mg/100g with %RDA range of 6-9% while the content of NAC ranged from 283.5-487.70 mg/100g with %RDA range of 6-10%. NAC showed higher sodium content with wheat, maize and rye having 49.7mg/100g, 54.5mg/100g and 32.5mg/100g respectively. Finger millet (49mg/100g) showed the highest value for AC. The second and the third highest values among the AC are 28.3 mg/100g (teff) and 30.7mg/100g (acha). The sodium content (9.7 mg/100g) of pearl millet is the lowest of all the cereals studied. Both classes have very low %RDAs of less than 5%. The mean values for zinc content of AC are all less than 2.8 mg/100g calculated for sorghum except for teff which has a value of 10.5 mg/100g. Barley has the highest zinc content of 3.2mg/100g among NAC. Rye has 2.8 mg/100g while oat have the lowest value 2.6 mg/100g. Apart from teff with zinc %RDA of 95% all other cereals in this study have %RDAs less than 30%.

Table 2. *Mean Mineral Composition (mg/100g) and Recommended Dietary Allowance (RDA)*.*

	African Cereals					Non-African Cereals				
	Pearl[a] Millet	Finger[b] Millet	Acha[c]	Teff[d]	Sorgh.[e]	Wheat[f]	Maize[g]	Barley[h]	Oat[i]	Rye[j]
Ca	32.0 (2%)	275.0 (21%)	19.6 (2%)	168.1 (13%)	22.3 (2%)	37.0 (3%)	19.5 (2%)	54.0 (4%)	29.5 (2%)	49.5 (4%)
Cu	9.8 (1089%)	0.5 (56%)	0.5 (56%)	2.9 (322%)	1.4 (156%)	0.9 (100%)	0.3 (33%)	0.6 (67%)	0.4 (44%)	0.4 (44%)
Fe	8.5 (106%)	6.7 (84%)	2.9 (36%)	13.7 (171%)	25.0 (313%)	4.5 (56%)	2.8 (35%)	5.3 (66%)	5.3 (66%)	3.5 (44%)
Mn	1.0 (43%)	3.6 (157%)	2.3 (100%)	4.1 (178%)	2.1 (91%)	19.4 (843%)	0.8 (35%)	1.7 (74%)	4.2 (183%)	2.6 (113%)
Mg	153.3 (37%)	135.0 (32%)	87.3 (21%)	175.0 (42%)	174.0 (41%)	136.5 (33%)	75.3 (18%)	135.0 (32%)	129.2 (31%)	141.5 (34%)
P	359.0 (51%)	273.3 (39%)	218.0 (31%)	414.1 (59%)	364.7 (52%)	441.4 (63%)	217.3 (31%)	385.3 (55%)	325.0 (46%)	351.0 (50%)
K	402.0 (9%)	314.0 (7%)	268.5 (6%)	380.3 (8%)	440.0 (9%)	361.0 (8%)	283.5 (6%)	471.3 (10%)	426.5 (9%)	487.7 (10%)
Na	9.7 (1%)	49.0 (3%)	30.7 (2%)	28.3 (2%)	10.7 (1%)	49.7 (3%)	54.5 (4%)	15.7 (1%)	14.0 (1%)	32.5 (2%)
Zn	2.7 (25%)	1.9 (17%)	2.1 (19%)	10.5 (95%)	2.8 (25%)	2.7 (25%)	3.0 (27%)	3.2 (29%)	2.6 (24%)	2.8 (25%)

Sources: *[17], [a][18, 20-21], [b][18, 20, 29], [c][24-26], [d][18, 33-34], [e][18, 20, 37], [f][18, 38-39], [g][18, 37, 42], [h][40, 47-48], [i][51-53], [j][51-52, 60]

2.3 Amino Acid Composition

The amino acid compositions reported in different research papers (3 papers each) of the cereals under investigation were analysed and compared with their respective %RDA. Acha (2.7 g/100g) and rye (2.3 g/100g) are the richest in cystine contents among the cereals. The other cereals all have values less than 1.8 g/100g for wheat. With finger millet, acha and teff having the highest methionine contents of 3.3 g/100g, 5.0 g/100g and 3.0 g/100g respectively, and with maize, oat and barley having 2.3 g/100g, 1.8 g/100g and 1.9 g/100g of methionine respectively, it is observed that AC contain higher methionine content than NAC. A high total sulphur amino acids (cysteine+methionine) content was observed in finger millet (4.8 g/100g), acha (7.7 g/100g) and teff (4.4 g/100g). The %RDAs of the total sulphur amino acids (cysteine+methionine) content in the cereals in this study are above 111% except for sorghum (76%). Isoleucine content of AC ranged from 3.5 g/100g (finger millet) to 4.5g/100g (pearl millet) while that of NAC ranges from 3.3 g/100g (wheat) to 4.0 g/100g (oat). Wheat was found to have the lowest %RDA for Isoleucine content of 118%. High leucine values were observed in both classes of cereals. However, AC exhibited higher leucine content in pearl millet (11.6 g/100g), acha (10.5 g/100g) and sorghum (12.8 g/100g) compared to those exhibited by maize (11.9 g/100g), oat (7.4 g/100g), and wheat and barley (6.5 g/100g). The %RDAs of leucine in AC are all above 105%. While %RDAs above 100% was observed for maize and oat, %RDA of the other AC fell below 100%. In general, cereals are limited in lysine content and vary with cultivar [65] but NAC showed clear superiority over AC in the aspect of lysine content with NAC lowest value (3.4 g/100g) being greater than AC highest value (2.5 g/100g). %RDAs of lysine in AC ranged from 28-43% and %RDAs of lysine in AC ranged from 59-69%. The differences between phenylalamine, threomine and tryptophan content of AC and NAC respectively are small but significant. Acha (5.7 g/100g), pearl millet (5.6 g/100g), oat (5.3 g/100g) and barley (5.1) have the highest Phenylalamine content of the cereals studied. Tyrosine in NAC is higher with maize and oat having the highest values of 3.6 g/100g and 3.4 g/100g respectively whereas pearl millet (3.0 g/100g), acha (3.5 g/100g) and teff (3.0 g/100g) have the highest values in AC class. Acha has the highest aromatic amino acids content (Phenylalamine+Tyrosine) among all the cereals. The %RDAs of Phenylalamine+Tyrosine ranged from 92-146% in AC and in AC and 66-87% in NAC. Acha (4.0 g/100g), maize (3.8 g/100g), pearl millet (3.6 g/100g) and finger millet (3.5 g/100g) have the highest threomine content. %RDA of threomine content ranged from 85-118% in AC and 76-112% in NAC. Tryptophan content of AC are higher than those of NAC with the first two highest Tryptophan content values: 2.2 g/100g (acha) and 1.6 g/100g (finger millet) higher than those of all the NAC (0.7–1.5 g/100g). As observed by Devi *et al.* [65], tryptophan in cereals is limited. This is observable in sorghum (73% RDA), maize (73% RDA) and rye (64% RDA) with relatively lower %RDAs but an exceptional %RDA of 200% was observed in acha. Finger millet at 6.3 g/100g and acha at 5.7 g/100g of valine are the highest values for AC, higher than the two highest values of NAC as recorded for maize (5.2 g/100g) and oat (5.4 g/100g). %RDAs of valine in AC ranged from 129-186% and ranged from 117-154% in NAC. With the exception of wheat (99%) and rye (98%), %RDAs of total amino acid content of the cereals in this study are above 100% with Acha having the highest %RDA value of 144%.

Table 3. *Mean Amino Acid Composition (g/100g) and Recommended Dietary Allowance (RDA)*.*

	African Cereals					Non-African Cereals				
	Pearl[a] Millet	**Finger[b] Millet**	**Acha[c]**	**Teff[d]**	**Sorgh.[e]**	**Wheat[f]**	**Maize[g]**	**Barley[h]**	**Oat[i]**	**Rye[j]**
Cys	1.2	1.5	2.7	1.4	0.9	1.8	0.9	1.3	NA	2.3
Met	1.6	3.3	5.0	3.0	1.0	1.3	1.9	1.8	1.9	1.5
Cys+Met	2.8 (112%)	4.8 (192%)	7.7 (308%)	4.4 (176%)	1.9 (76%)	3.1 (124%)	2.8 (112%)	3.1 (124%)	NA NA	3.8 (152%)
Iso	4.5 (161%)	3.5 (125%)	4.1 (146%)	3.9 (139%)	3.8 (136%)	3.3 (118%)	3.8 (136%)	3.6 (129%)	4.0 (143%)	3.4 (121%)
Leu	11.6 (176%)	7 (106%)	10.5 (159%)	7.5 (114%)	12.8 (194%)	6.5 (98%)	11.9 (180%)	6.5 (98%)	7.4 (112%)	6.0 (91%)
Lys	2.0 (34%)	1.6 (28%)	2.5 (43%)	2.2 (38%)	2.0 (34%)	3.5 (60%)	3.4 (59%)	3.5 (60%)	4.0 (69%)	3.4 (59%)
Phe	5.6	3.8	5.7	4.9	4.1	4.7	4.8	5.1	5.3	4.7
Tyr	3.0	2.9	3.5	3	1.7	2.0	3.6	2.8	3.4	1.9
Phe+Tyr	8.6 (137%)	6.7 (106%)	9.2 (146%)	7.9 (125%)	5.8 (92%)	6.7 (106%)	8.4 (133%)	7.9 (125%)	8.7 (138%)	6.6 (105%)
Thr	3.6 (106%)	3.5 (103%)	4.0 (118%)	3.3 (97%)	2.9 (85%)	2.6 (76%)	3.8 (112%)	3.1 (91%)	3.4 (100%)	3.1 (91%)
Try	1.3 (118%)	1.6 (145%)	2.2 (200%)	1.2 (109%)	0.8 (73%)	1.5 (136%)	0.8 (73%)	1.4 (127%)	1.3 (118%)	0.7 (64%)
Val	4.5 (129%)	6.5 (186%)	5.7 (163%)	5.5 (157%)	4.9 (140%)	4.1 (117%)	5.2 (149%)	4.8 (137%)	5.4 (154%)	4.6 (131%)
Total	39.09 (122%)	35.25 (110%)	46.15 (144%)	36.05 (113%)	34.9 (109%)	31.5 (98%)	40.39 (126%)	34.04 (106%)	36.35 (114%)	31.6 (99%)

Sources: *[64], [a][10, 18, 22], [b][18, 30-31], [c][18, 24, 27], [d][18, 30, 35], [e][15, 31, 36], [f][15, 39-40], [g][15, 41, 44], [h][15, 40, 45], [i][15, 40, 54], [j][15, 39, 54]

2.4. B-Vitamin Composition

Cereals contain no vitamin C or vitamin B12, no vitamin A and, apart from yellow maize, no beta-carotene [58]. However, cereals are an important source of most B vitamins, especially thiamine, riboflavin and niacin [47]. While there is enough information and research works on B vitamins in NAC, there is paucity of information on vitamin composition of AC. This was observed while sourcing for data and information on cereals. The B vitamins of cereals under investigation as reported in available papers were analysed and compared with their respective RDA. Thiamine content was observed to be higher in NAC when compared to AC. Thiamine content of AC ranged from 0.10-0.42mg/100g. Thiamine content of NAC ranged from 0.32-0.72mg/100g. Thiamine content of acha (8% RDA) was observed to be very low and the highest thiamine content was in oat (60% RDA). Riboflavin contents in AC ranged from 0.05-0.27 mg/100g and have %RDAs that ranged from 4-21%. Its content in NAC ranged from 0.10-1.05 mg/100g with %RDA that ranged from 8-81%. Oat and barley showed high thiamine contents that are 71% and 81% of their respective RDA. Niacin content in cereals was observed to be higher than thiamine and riboflavin contents. It was also observed to have the lowest %RDA. There is little difference in thiamine content when AC and NAC are compared. Niacin content in AC ranged from 1.10-4.30 mg/100g with RDA that ranged from 7-27%. Niacin content in NAC ranged from 0.54-5.29 mg/100g with %RDA that ranged from 3-33%. Finger millet (7%) and oat (3%) was observed to have the lowest %RDAs.

Table 4. *B-Vitamin Composition (mg/100g) and Recommended Dietary Allowance (RDA)*.*

	African Cereals					Non-African Cereals				
	Pearl[a] Millet	**Finger[b] Millet**	**Acha[c]**	**Teff[d]**	**Sorgh,[e]**	**Wheat[f]**	**Maize[g]**	**Barley[h]**	**Oat[i]**	**Rye[j]**
Thiamine	0.38	0.42	0.10	0.39	0.31	0.42	0.38	0.54	**0.72**	0.32
	(32%)	(35%)	(8%)	(33%)	(26%)	(35%)	(32%)	(45%)	(60%)	(27%)
Riboflavin	0.21	0.19	0.05	0.27	0.15	0.10	0.20	1.05	0.92	0.25
	(16%)	(15%)	(4%)	(21%)	(12%)	(8%)	(15%)	(81%)	(71%)	(19%)
Niacin	2.80	1.10	2.00	3.36	4.30	5.29	3.62	2.46	0.54	4.3
	(18%)	(7%)	(13%)	(21%)	(27%)	(33%)	(23%)	(15%)	(3%)	(27%)

Sources: *[17], [a][9], [b][9], [c][66], [d][67], [e][9, 58], [f][9, 58, 68], [g][9, 58, 68], [h][58, 68], [i][58, 68], [j][58, 68]

3. Conclusion

AC have low moisture contents, lower than those of other cereals. This may be because they are grown with limited water as often the case in Africa. NAC are richer than AC in Protein, though Pearl millet is exceptionally as rich in protein as wheat. The protein in barley, pearl millet and wheat can substitute animal protein in meals if they are consumed as whole grain and if they are properly processed to make the proteins digestible and bioavailable. AC like other cereals have low fat content and can be recommended for people with overweight problem. NAC are richer in fibres than AC. Fibre and minerals tend to be concentrated in the outer bran and aleurone layers of cereal grains, the fibre content of a cereal will depend on the extent to which these layers are removed during processing [57]. Whole grain of NAC, finger millet and pearl millet can provide a good amount of fibre in a diet and can be recommended for people with overweight, diabetes and obesity problem. AC are richer in carbohydrate and ash content, thus are better sources of energy and minerals.

The richest cereals in calcium, copper, iron, magnesium and zinc are of AC category while the richest cereals in manganese, phosphorus, potassium and sodium are of NAC category. The calcium contents of finger millet and teff are relatively very high compared with other cereals. The copper content of Pearl millet (1089% RDA) and the manganese content of wheat (843% RDA) are higher than what is required in the body. This may not be healthy because copper and manganese are heavy metals and only a trace amount is required [61-63]. AC are very good sources of amino acids. Compared to NAC, they are generally richer in all the amino acids covered in this study except for lysine and tyrosine. Acha is very rich in sulphur amino acid (methionine and cysteine), two human-vital amino acids almost deficient in the major cereals. The highest lysine content was observed in oat. In this study of Acha grains was found to be the richest in amino acid and contains the highest quantity of total amino acid, sulphur amino acids (methionine+cysteine), aromatic amino acids (specifically phenylalamine), threomine and tryptophan (all above their RDAs). While there is enough information and research works on B vitamins in NAC, there is paucity of information on vitamin composition of AC. B-vitamins were observed to be higher in NAC when compared to AC. Barley and oat are the best sources of thiamine and riblflavin among the cereals studied.

Though NAC have higher protein, fibre and B-vitamins contents, AC showed superiority in amino acid composition and distribution. AC have less fat and more carbohydrate therefore it is as a healthier source of energy in meals especially when eaten alone. AC and NAC are both good sources of minerals with very little difference in ash contents.

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