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Research Paper

BETA-GLUCAN PROFILE IN TROPICAL MAIZE GENOTYPES: EFFECT OF ISOLATION METHOD

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Abstract

Cereal beta-glucan (β-glucan) is a soluble dietary fibre with important physiological functions which promote health and well-being of consumers. While oat and barley are conventional sources, very little is known about β-beta-glucan in maize. The wide variation in β-glucan content reported arises from differences in genotype of the cereal and the isolation method, which includes enzymic and non-enzymic techniques. The objective of this research was to evaluate seventeen tropical maize genotypes for their β-glucan content using nonezymic and enzymic methods and to determine correlation with proximate components. Among the non-enzymic methods, extractability of maize β-glucan was highest in the acid isolation followed by alkaline and lastly, hot water isolation. The enzymic method showed higher efficiency of extractability than nonenzymic methods. Gum yield from maize ranged from 191.0 to 419.0 g kg^{-1} representing 14.5 and 25.6 g kg^{-1} of pure β-glucan. Significant and positive correlation was found between β-glucan and protein and a strong negative correlation between β-glucan and nitrogen-free extract. Acid and enzyme-based isolation methods demonstrated higher extractability for maize β-glucan. Beta-glucan and crude protein were found to be positively correlated. Among the maize types evaluated, hybrid varieties demonstrated the highest β-glucan content.

Key words: maize β-glucan; gum yield, isolation method, breeding potential.

INTRODUCTION

In developing countries, maize (*Zea mays* L.) is a major staple crop which is cultivated on more than 96.5 million hectares[1] and supplies over 65 % of the total calories and up to 60 % of the protein intake.[2,3,4,5] Maize is also used as feed and a raw material for many industries.

Value addition to agricultural commodities has received attention from both the food industry and researchers, given that, it increases grower returns, controls postharvest losses, and satisfies demands for functional foods. A high-value component present in cereals, which is known to impart health benefit, is β-glucan. Cereal β-glucan is a polysaccharide of β-(1→3) glucopyranosyl units interspersed with β-(1→4) branching to form cellotriosyl and

cellotetraosyl chains. Commercial quantities of β-glucan are typically obtained from oat (3 to 11 %) and barley (2 to 8 %).[6,7,8] As soluble dietary fibre, consumption of high levels of β-glucan is protective and beneficial in the management of chronic diseases such as chronic bowel disease, colon cancer, cardiovascular disease and diabetes.[9,10]

Various animal models and clinical trials have demonstrated the physiological activity of β-glucan in lowering of total and low density lipoprotein (LDL) cholesterol level,[11,12,13] hence reducing the risk of coronary heart disease (CHD), in addition to lowering the risk of diabetes by depressing postprandial blood sugar level.[14,15,16,17,18] These empirical observations have led to the recommendation of β-glucan-rich cereals like oat and barley for dietary intervention in both prevention and management of cardiovascular diseases and type II diabetes. On the basis of an inverse relationship between dietary fiber intake and risk of CHD, the American Food and Drug Administration[19,20] has endorsed a health claim on consumption of at least 3 g/day of soluble β-glucan from whole-grain barley to reduce plasma total cholesterol by 5-8%. Similar oat β-glucan claim exist in Canada, the United Kingdom, Sweden, and The Netherlands.[21] In 2011, the European Commission authorized another health claim for barley and oat at 4 g/30 g carbohydrate in a meal for reduction in post-prandial blood glucose level.[22]

The physiological activity of β-glucan polymer is attributed to its increase in the viscosity of intestinal contents and delayed intestinal absorption of glucose[23,24,25,26] and lipids, increased excretion of bile acids, and inhibition of absorption and reabsorption of cholesterol and bile acids.[27,28,29] Wilson et al.[28] also attributed the cholesterol-lowering effect of beta-glucan to fermentation of β-glucan in the colon, resulting in production of short-chain fatty acids, which impede cholesterol biosynthesis. This research information has contributed to development of cultivars of barley having high β-glucan content for human nutrition.

Using doubled haploid (DH) and single seed descent method of breeding for reduced β-glucan, in barley, Powell et al.[30] reported that gum content was controlled by a simple additive genetic system involving allelism in the parents, suggesting that β-glucan content is genotype-dependent. Significant negative genetic correlations were observed between β-glucan content, thousand-grain weight and plant height in the doubled haploid genotypes. Absence barley and oats from tropical West Africa necessitates search for alternative sources of β-glucan in tropical cereal grains. Satija and Hu[31] stated that future research on dietary fiber should focus on various food sources of fiber, including different types of whole grains, legumes, fruits, vegetables, and nuts, as well as resistant starch in relation to cardiovascular disease risk and weight control and study different ethnic groups and populations with varying sources of dietary fiber.

Like other food polymers, the physiological activity of beta-glucan is modified by its physical form, method of isolation, and degree of polymer breakdown. For this reason, the enzymic and nonenzymic methods for isolation of β-glucan have been developed with the aim of preserving native structure and ensuring quality. Ahmad et al.[32,33] evaluated extractability of β-glucan from barley and oat using acid, alkaline, hot water and enzymic extraction methods and reported that for barley, hot water produced the highest recovery while the alkaline method produced the least extractability. For oat, enzyme isolation method gave highest recovery and acid extraction method produced the least recovery.

Literature is scanty with regard to maize as a source of β-glucan. The influence of proximate composition of cereals on β-glucan content has not been investigated. A relationship between the components and β-glucan would indicate correlated response which can be exploited in breeding for β-glucan enhancement in maize. This research seeks to evaluate the β-glucan content of seventeen maize genotypes originating from Ghana and investigate its correlation with proximate composition.

MATERIALS AND METHODS

Maize genotypes

Seventeen maize genotypes provided by the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (C.S.I.R.), Kumasi, Ghana, were evaluated in current study. The genotypes were chosen to cover a wide array of breeding materials, incorporating 3 hybrid

cultivars, 11 open-pollinated varieties (OPVs) released in Ghana from 1961 to 2007, and 3 landraces. The names and designations of the genotypes are presented in Table 1.

Morphological characterization and flour preparation

Maize flour of particle size 0.2 mm were evaluated for morphological characteristics including kernel texture, colour, and 100-kernel weight and proximate composition.

Proximate composition

Official methods of A.O.A.C. were used to determine moisture, ash, crude fat, total nitrogen and crude fibre [34], Protein content was determined by multiplying % total nitrogen by a factor of 6.25. Available carbohydrate content was calculated by difference.[34]

Extractability of gum

The extractability of gum, the component which expresses β-glucan content in maize was studied using four wet extraction methods comprising aqueous alkali process, hot water , acid extraction[32] and alcohol-based enzyme extraction.[35] All extractions were performed on the dried and defatted flour with at least two replications. For the purpose of protecting macromolecular components in maize flour, native enzymes were inactivated by pretreatment involving reflux of flour with 80% ethanol followed by heating at 55 ^{o}C for 90 min in 1 M sodium hydroxide. Following centrifugation, the supernatant was subjected to the four different treatments. In the aqueous alkali process, the supernatant was adjusted to pH 10 with three parts of 1 M sodium hydroxide to solubilize β-glucan and protein while starch and other forms of fibre remained insoluble. In the acid extraction method, 1 M citric acid with heating, while in the hot water extraction 10 parts of hot water (80 ^{o}C) performed the same task. Centrifugation followed by precipitation of protein from the supernatant at their respective isoelectric points left behind intact β-glucan. The alcohol-based enzyme extraction technique involved sequential treatment of the flour with bromelain (E.C. 3.4.22.32, pineapple stem) and α-amylase (E.C. 3.2.1.1, *Bacillus subtilis*), purchased from Sigma-Aldrich, St.Loius, MO, U.S.A, to hydrolyze protein and starch, respectively, leaving the β-glucan-rich fibre fraction intact.

Purification of B-Glucan

Purified β-glucan was prepared from gum samples using the non-alkaline and non-enzymatic procedure of Ghotra[36] involving solubilization of gum in deionized water at 82^{o}C followed by centrifugation at 4100 r.p.m. and precipitation of β-glucan from the supernatant with absolute ethanol (1:1 v/v). The precipitate was dried to constant mass and percentage recovery of purified β-glucan calculated. Results of extractability are reported on dry matter basis.

Chemical analyses

Gum materials were evaluated for moisture, crude fat, ash and protein content as outlined earlier. Gum isolates having limiting contents of protein and fat were assayed for starch content. Total starch was assayed using Megazyme assay kit (Megazyme International, Wicklow Ireland), which is based on A.O.A.C. No. 996.11.[34]

Beta-Glucan Assay

Pure β-glucan content was determined using Mixed Linkage assay kit (K-BGLU) of Megazyme (Megazyme International, Ireland) based on the McCleary method.[37] The β-Glucan contents of gums were reported on dry weight basis

Colour of maize β-D-glucan

The colour of maize gums was measured using the L*, a* and b* colour space (CIELAB space) with Colorimeter CR-200 (Minolta, Osaka, Japan).[32] On the CIELAB space, the central vertical axis, L*, represents lightness having values ranging from 0 (black) to 100 (white). The a* and b* axes measure colour, such that a* ranges from –a (green) to +a (red) and b* from –b (blue) to +b (yellow).

Statistical analyses

Means and analyses of variance of triplicate measurements were computed. Differences in means were located by the Least Significant Difference (LSD) test. Pearson correlation coefficients between β-glucan and 100-kernel weight and proximate composition parameters were computed using SAS 9.1.3 (SAS Institute, Cary, NC).[38]

RESULTS AND DISCUSSION

Morphological characterization

Maize kernels were classified on the basis of their colour and texture. Twenty-three percent of the kernels were yellow and 77% were white. The predominant kernel texture was dent (Table 1). A wide variation in 100- kernel weight was observed among the maize varieties, covering a range of 17.33 g for 'Dodzi' to 34.0 g for 'Mamaba' (Table 1).

Proximate Composition

Moisture content of maize kernels ranged from 40.0 g kg^{-1} for 'Mamaba' to 80.0 g kg^{-1} for 'Aburohemaa'. Fat content varied between a low value of 21.0 g kg^{-1} for 'Dodzi' and a highest value of 58.2 g kg^{-1} for 'Obatanpa GH' (Table 1). The fat content for 'Obatanpa GH' is higher than that of sorghum (39.0 g kg^{-1}), wheat (14.0 g kg^{-1}) and barley (34.0 g kg^{-1}) but comparable with oat (59.0 g kg^{-1}).[39]

Table 1. Proximate composition and gum yield of maize by the non-enzymic isolation method.

Name	**Variety**	**100-KW (g)**	**Moisture (g kg^{-1})**	**Fat (g kg^{-1})**	**Protein (g kg^{-1})**	**Ash (g kg^{-1})**	**Fibre (g kg^{-1})**	**NFE‡ (g kg^{-1})**	**Hot water (g kg^{-1})**	**Acid (g kg^{-1})**	**Alkaline (g kg^{-1})**
'Mamaba'	Hybrid Common	34.0^{c}± 0.1	40.0^{a} ±0.8	45.0^{b} ±0.9	126.0^{a} ±0.7	8.0^{a} ±0.2	22.0^{b} ±0.5	760.0^{b} ±0.6	ND	156.0^{a} ±0.8	73.4^{a} ±0.3
'Suwan 1 QPM'	Hybrid QPM	27.9^{ba} ±0.2	56.0^{b} ±0.4	38.0^{a} ±0.6	121.0^{a} ±0.1	14.0^{a} ±0.1	40.0^{c} ±0.9	731.0^{b} ±0.8	ND	351.7^{b} ±3.1	63.0^{a} ±0.3
'Obatanpa GH'	OPV* QPM	18.1a ± 0.0	57.0^{b} ±0.2	58.0^{b}± 0.7	173.0^{c} ±0.7	14.0^{a} ±0.1	21.0^{b} ±0.1	677.0^{a} ±1.1	23.3^{e} ±0.3	414.0^{c} ±3.0	71.0^{a} ±0.6
'Omankwa'	OPV Common	26.8^{b} ± 0.01	57.0^{b} ±0.6	28.0^{a}± 0.5	94.0^{a} ±0.7	10.0^{a,} ±0.2	22.0^{b} ±0.3	707.0^{a} ±1.45	5.5 ±0.0	144.0^{a} ±2.8	44.0^{c} ±0.4
'GH9'	Hybrid QPM	24.4^{a} ± 0.0	64.0^{b} ±0.6	57.0^{b} ±0.1	129.0^{a} ±0.2	10.0^{a,} ±0.3	18.0^{a} ±0.1	722.0^{a} ±0.4	ND	448.0^{c}± 9.3	184.0^{d} ±0.6
'Catete'	Landrace Common	20.0^{a} ± 1.8	66.0^{b} ±0.0	55.0^{b} ±0.5	137.0^{b} ±0.5	23.0^{b} ±0.7	14.0^{a} ± 0.1	705.0^{a} ±1.4	4.0^{b} ±0.0	186.0^{a}± 2.63	43.0^{c} ±0.3
'Dodzi'	OPV Common	17.3^{a} ± 0.0	64.0^{b} ±0.4	21.0^{a} ±0.3	133.0b ±0.8	13.0^{a} ±0.2	19.0^{b} ±0.3	750.0^{b} ±0.4	ND	148.0^{a}± 1.4	ND
'Okomasa'	OPV Common	25.8^{b} ± 0.0	59.0^{b,c} ±0.1	40.0^{a} ±0.2	105.0^{a} ±0.0	5.0^{a} ±0.3	6.0^{a} ±0.1	786.0^{b} ±0.8	0.0^{d} ±0.0	189.0^{a} ±2.9	ND
'ABH'	OPV	27.7^{b}	80.0^{c}	57.0^{b}	98.0^{a}	12.	16.	737.	0.0^{d}	164.0^{a}±	57.0^{bc}

	Common	± 0.0	±0.3	±0.5	±0.1	0[a] ±0.1	0[a] ±0.11	0[b] ±1.8	±0.0	1.4	±0.5
'Abontem'	OPV QPM	21.5[a] ± 0.0	68.0[b] ±0.0	50.0[b] ±0.8	90.0[a] ±0.75	10.0[a,] ±0.1	17.0[a] ±0.2	765.0[b] ±0.43	2.0[c] ±0.0	191.0[a] ±1.5	207.0[e] ±1.3
'Sotubaka'	Landrace Common	20.3[a] ± 0.03	66.0[b] ±0.2	56.0[b] ±0.2	116.0[a] ±0.7	13.0[a,] ±0.1	15.0[a] ±0.5	735.0[b] ±0.4	1.0[c] ±0.0	258.0[b] ±0.5	82.0[f] ±0.4
'Dorke'	OPV Common	28.5[b] ± 0.10	50.0[a] ±0.5	48.0 ±0.1	131.0[b] ±0.1	7.0[a] ±0.3	19.0[b] ±0.1	746.0[b] ±0.8	ND	83.0[d] ± 1.1	38.0[c] ±1.2
'Akposoe'	OPV QPM	24.4[a] ± 0.02	55.0[a] ±0.1	49.0[b] ±0.1	139.7 ±1.2	10.0[a,] ±0.2	16.0[a] ±0.4	732.0[b] ±0.9	21.0[a] ±0.1	393.0[bc] ±4.1	0.0[d] ±0.0
'Abeleehi'	OPV Common	25.0[a] ± 0.1	50.0[a] ±0.1	52.0[b] ±0.2	104.0[a] ±0.5	15.0[a] ±0.6	3.0[a] ±0.3	776.0[b] ±1.1	0.0[d] ±0.0o	517.0[d] ±4.1	53.0[c] ±0.4
'Safita 2'	OPV Common	19.2[a] ± 0.01	54.0[a] ±0.1	33.0[a] ±0.27	137.0[b] ±1.80	10.0[a] ±0.55	8.0[a] ±0.1	758.0[b] ±0.86	12.0[a] ±0.03	262.0[b] ±20.2	75.0[f] ±0.4
'Ohawu local'	Landrace Common	22.3[a] ± 0.2	77.0[c] ±0.1	44.0[b] ±0.4	123.0[a] ±0.3	10.0[a] ±0.2	17.1[a] ±0.0	739.0[b] ±0.7	ND	135.0[a] ±1.6	51.0[bc] ±0.7
'Golden Jubilee'	OPV QPM‡	28.5[b,] ± 0.1	67.0[b] ±0.1	49.0[b] ±1.55	91.2[a] ±0.01	8.0 ±0.15	10.0[a] ±0.3	775.0[b] ±0.1	ND	403.0[c]± 9.7	79.0[af] ±1.3
LSD		**7.8**	**15.7**	**20.8**	**39.5**	**7.7**	**15.0**	**53.7**	**15.9**	**60.7**	**94.6**
CV(%)		**18.5**	**16.9**	**25.3**	**18.2**	**39.5**	**52.3**	**4.06**	**132.3**	**48.9**	**81.6**

Numbers in columns followed by different superscripts are significantly different at P<0.05. *Open pollinated variety. ‡Nitrogen Free Extract; †Quality Protein Maize

Crude protein content of maize varied between 80.0 g kg^{-1} for 'Abontem' and 171.0 g kg^{-1} for 'Obatanpa GH' (Table 1), demonstrating higher protein content than sorghum (83.0 g kg^{-1}) but comparable to that of barley (110.0 g kg^{-1}), oat (93.0 g kg^{-1}) and wheat (107.0 g kg^{-1}).[39] The ash content of maize varied (P<0.05) between 55.0g kg^{-1} for 'Okomasa' and 255.0 g kg^{-1} for 'Catete' Nitrogen-Free Extract (NFE) ranged between 677.1 to 785.9 g kg^{-1}. In this research NFE was representing starch.

Gum Yield and β-glucan Recovery

Gum is the product recovered after solubilization and separation of non-β-glucan components from the grain.[32,33] It can be referred to as crude β-glucan as it is expected to contain some fat, protein, starch and ash. In the non-enzymic methods of isolation, a wide variation in gum content was observed. The hot water extraction method was characterized by very low and

undetectable gum with the highest value of 23.3 g kg^{-1} recorded for 'Obatanpa GH'. In the alkaline isolation method, though gums were present, 14 out of 17 cultivars had gum content below 100 g kg^{-1} with 'Obatanpa GH' having 71 g kg^{-1} and a highest value of 207 g kg^{-1} recorded for . 'Abontem'In contrast, acid isolation produced the highest extractabilityof gum ranging from a low value of 83.4 for 'Dorke' to 517.0 g kg^{-1} for Abeleehi (Table 1) and 'Obatanpa GH' recording 414 g kg^{-1}. The low efficiency of β-glucan extraction by hot water was also reported for barley by Symons and Brennan.[40] In contrast, Ahmad et al.[32] reported highest gum yield from barley by hot water extraction (54.0 g kg^{-1}), followed by enzyme extraction (52.0 g kg^{-1}), then acid process (46.5 g kg^{-1}), with alkaline extraction recording the lowest gum yield of 39.4 g kg^{-1}. Wide variability of the hot water and alkaline isolation methods were supported by high coefficient of variation of 132 and 81.6 %, respectively. This variability is due to both extraction method and genotype.

Unlike the hot water and alkaline isolation methods where gum content were lower than crude fibre, the acid extraction method produced higher gum content than crude fibre in about 60 % of the cultivars (Table 1). This behavior was unexpected as fibre represents non-starch polysaccharides including β-glucan, celluloses, arabinoxylans, pectin, hemicelluloses and lignin.[41] This anomaly may be attributed to the inability of the acid to remove non-fibre components, such as starch from the flour. However Ahmad et al.[32] recorded higher fibre content than gum content irrespective of isolation method

Following the non enzymic isolation methods, three cultivars namely, 'Obatanpa GH', 'Abeleehi' and 'GH 9' having gum contents exceeding 410.0 g kg^{-1} were selected for further studies including enzyme-based alcohol extraction and determination of impurities. Table 2 shows descriptive statistics of gum yield from the three cultivars using the enzymic method of isolation compared to the nonenzymic isolation method.

Table 2. Descriptive statistics of yield of gum from three genotypes by means of the enzymatic and non-enzymic method of isolation extraction

Cultivar	Mean enzymic gum yield (g kg^{-1})	Mean non-enzymic gum yield (g kg^{-1})
'Abeleehi'	332.0 ±12.4	517.2 ±41.1
'Obatanpa GH'	418.9 ±31.8	414.2 ±30.4
'GH9'	381.8 ±20.0	447.9 ±93.0
Mean	399.7	459.7
Standard deviation	6.56	6.98
LSD	149.3	60.7
¶CV (%)	16.42%	15.20
†SEM	2.19	2.33

†Standard error of mean ¶Coefficient of variation

Using the enzymic method, the recovery of gum ranged between 332.0 g kg^{-1} for ''Abeleehi' to 419.0 g kg^{-1} for 'Obatanpa GH' (Table 3) which corresponds to recovery rate of 428.0 to 619.0 g kg^{-1}, respectively. Variability in gum content of the enzymic isolation method was very small ($P>0.05$) in contrast to the non-enzymic methods. A paired comparison test at a confidence level of 95 % showed no significant difference ($P>0.05$) in yield between the alcohol-based enzyme and acid extraction methods. Generally, gum yield from maize was lower (363.9 to 439.2 g kg^{-1}) compared to those of barley (814.0 g kg^{-1}) and oat (868.0 g kg^{-1}).[32,33]

Maize genotypes were grouped into hybrids, OPVs and landraces. Hybrid varieties exhibited the highest gum yield regardless of the isolation method, while landraces gave lowest gum yield. The higher concentration of gum in the hybrids may probably have been an indirect benefit arising from linkage of beta-glucan with the trait of interest.

Table 3. Variation in mean gum yield as a function of cultivar type (pooled data).

	Gum yield (g kg^{-1})		
Cultivar type	Number screened	Alkaline	Acid
Hybrids	3	104.1^{b}±34.6	318.3^{b}±137.2
OPVs	11	57.1^{a}±20.1	267.2^{c}±134.2
Landraces	3	50.9^{a}±17.7	191.1^{a}±53.8

Numbers in columns followed by different superscripts are significantly different (P<0.05), followed by their respective standard deviation.

Chemical Composition of Acid Extracted Isolates

The efficiency of gum isolation from acid extraction and enzymic methods were determined by measuring the residual moisture, fat, protein, ash and NFE. Table 4 shows the chemical constituents of the three cultivars that were selected for further studies. Efficiency of the acid and enzymic isolation methods in removing impurities from the flour was similar. Residual moisture ranged from 25.3 to 49.9 g kg^{-1}, fat from 5.0 to 27.9 g kg^{-1}, ash, 1.7 to 11.5 g kg^{-1} and protein from 4.1 to 17.3 g kg^{-1} for. (Table 4). Protein was reduced by about 90 %, fat by 65 %, while ash and moisture were reduced by about 50 %, resulting in an increase in NFE Working with barley; Ahmad et al.[33] reported 70.25 % removal of fat, 51.36 % removal of ash, and 51.4 % removal of protein by the enzyme extraction method. For oat gum isolation, fat was reduced by 77.2 %, ash by 38.1 %, and protein by 56.71 %.[33]

Starch is a major impurity in gum isolates.[33,42,43] The original starch content of the maize flour of 'Obatanpa GH' and 'Abeleehi' were found to be 851.4 ±1.07 and 750.2 ±0.92 g kg^{-1}, respectively. In the enzyme isolates, residual starch content ranged from a least value of 1.7 g kg^{-1} for 'Obatanpa GH', 1.8 g kg^{-1} for 'GH 9', to 2.7 g kg^{-1} in 'Abeleehi' representing a percentage reduction of 99.7 %. For oat and barley, starch was reduced by 94.1 %[33] and 97.7 %[32], respectively.

For oat gum isolation by the acid extraction method, fat was reduced by 80.91 %, ash by 44.04 %, and protein by 47.80 %.[33] The high efficiency in removal of total nitrogen can be attributed to the iso-electric point of protein being favoured in the acidic range, hence thorough removal of proteinaceous matter from the flour during the extraction process.

Table 4. Efficiency of gum isolation method measured as residual proximate composition of gum

Parameter	Moisture (g kg^{-1})	Ash (g kg^{-1})	Fat (g kg^{-1})	Protein (g kg^{-1})	NFE (g kg^{-1})
Maize flour	56.9^{c}±0.70	12.8^{c}±0.39	55.7^{b}±0.43	134.8^{b}±3.02	739.8^{b}±4.23
Acid extracted gum	33.2^{a}±0.76 (42%)	6.6^{a}±0.30 (48 %)	19.7^{a}±0.23 (65 %)	9.0^{a}±0.34 (93 %)	941.6^{a}±0.83 (21 %)
Enzyme/alcohol gum	45.6^{b}±0.56 (20 %)	4.7^{b}±0.08 (63 %)	20.1^{a}±0.59 (64 %)	8.6^{a}±0.57 (94 %)	921.5^{a}±0.46 (20 %)

Numbers in rows followed by different superscripts are significantly different (p<0.05), followed by their respective standard deviations. Numbers in parenthesis are percentage removal of impurity.

No apparent trend was observed between gum yield and pure β-glucan. Pure β-glucan content of maize, ranged from a least value of 14.0 g kg^{-1} for 'Obatanpa GH', 16.8 g kg^{-1} for 'Abeleehi', and 25.6 g kg^{-1} in 'GH 9'. Ghana maize β-glucan concentrations in the current study was higher than

that reported for Turkey maize (5.0 to 13.0 g kg^{-1})[44], sorghum (1.2 g kg^{-1})[45], and wheat (5.2 to 10.0 g kg^{-1}).[46,47]

Correlation for β-glucan Concentration with Proximate Composition

A correlation analysis was performed on β-glucan with moisture, fat, protein, ash, fibre and nitrogen free extract. Table 5 shows the correlation coefficients and probability values. A strong negative and significant correlation (P<0.05) between β-glucan and NFE and significant and positive correlation between β-glucan and protein were observed. The *r*-square value of 0.96 and 0.40 indicate that 96 % and 40 % of the variation in β-glucan in maize is explained by variation in NFE and protein. It is expected that breeding for high protein in maize will result in a correlated response in β-glucan. Two of the genotypes which showed high β-glucan content were Quality Protein Maize (QPM). This suggests that more work is needed to confirm the relationship between QPM and β-glucan content in maize. Similar work on starch and β-glucan concentration in maize showed a significant (P= 0.04) but negative correlation (r = -0.77) between starch and β-glucan.[49,50]

Table 5. Correlation coefficients of β-glucan with kernel weight, moisture, fat, protein, ash, fibre and nitrogen free extract

	Moisture	Fat	Protein	Ash	Fibre	¶NFE
Moisture						
Fat	0.21 (0.43)					
Protein	-0.29 (0.26)	0.09 (0.70)				
Ash	0.17 (0.50)	0.22 (0.40)	0.30 (0.24)			
Fibre	-0.09 (0.74)	-0.17 (0.50)	0.21 (0.42)	0.11 (0.67)		
NFE	-0.11 (0.66)	-0.21 (0.40)	-0.58 (0.01)	-0.52 (0.04)	-0.48 (0.04)	
†BGLU	0.03 (0.91)	0.20 (0.42)	0.63 (0.006)	0.45 (0.06)	0.49 (0.04)	-0.98 (<0.01)

¶Nitrogen Free Extract; †β- glucan. Values in parenthesis are probability levels.

Colour

In the current study, the L* values for maize β-glucan gum ranged between 79.67± 0.13 for GH 9 and Abeleehi to 83.95 ±0.30 for 'Obatanpa GH'. This range of L* values are higher than those reported by Ahmad et al.[32] for barley β-glucan (68 to 77) The high degree of lightness (L*) of maize gums makes them good ingredient for baked products as well as transparent food systems[32,33] as they will not impart colour to the product in which they are used.

The b* values ranged from +11.57 to +21.57 indicating slightly yellowish appearance and suitability for incorporation of the gum in soup, dough and dips where it would impart the desirable cream to yellow colour. A b* value of +23.45 for oat gum[33] and +19.32 for barley gum[15] was similar to the +21.57 of 'GH 9' gum. The degree of yellowness is represented by positive b* values. The closer the b* value to 60, the deeper the yellow intensity. 'GH9'recorded the highest b* value of 21.57 which was significantly different (P<0.05) from 'Obatanpa GH' and 'Abeleehi' which recorded 13.33 ±0.03 and 11.57± 0.07, resulting in an overall faint yellow colour of gum respectively.

CONCLUSION

The acid and alcohol-based isolation methods gave the highest yield of gum and hot water and alkaline isolation methods demonstrated lower extractability. The genotypes 'Obatanpa GH' gave the highest gum yield by the enzymic method while 'Abeleehi' produced the highest gum yield with the acid isolation method. Hybrid varieties had the highest gum content while the

landraces had the lowest. Beta-glucan content of kernels was found to correlate with protein, fibre and nitrogen free extract. A striking feature was the negative correlation of β-glucan with starch content of the kernels.

With regard to actual β-glucan content of gums, 'GH 9' had the highest β-glucan of 25.6 g kg^{-1}. Maize with this concentration of β-glucan is enough to supply the WHO recommended level of 3 g/ day of β-glucan in the diet in order to maintain good health status with regard to blood sugar and cholesterol levels.

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