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Research Article

Nutrient and Antinutrient Composition of Winged Bean (*Psophocarpus tetragonolobus* (L.) DC.) Seeds and Tubers

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Many people in sub-Saharan Africa suffer from protein malnutrition; this results in negative health and economic impacts. Winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is a tropical underutilized legume with beneficial nutritional characteristics such as high protein content, which may help to alleviate these problems. The proximate composition (fat, moisture content, crude protein, ash, and carbohydrate) and antinutrient (tannin and phytate) level of winged bean seeds and tubers were determined using 50 accessions. In the processed seeds, accession Tpt17 had the highest protein content (40.30%) and Tpt48 the lowest (34.18%). In the unprocessed seeds, Tpt17 also recorded the highest crude protein (31.13%) with Tpt125 having the lowest (28.43%). In the tubers, protein content ranged from 19.07% (Tpt42) to 12.26% (Tpt10). The moisture content in the processed seeds ranged from 8.51% (Tpt42) to 6.72% (Tpt6); in the unprocessed seeds, it was between 8.53% (Tpt53) and 3.76% (Tpt14). In the processed seeds, the values of ash ranged from 4.93% (Tpt126) to 4.45% (Tpt15-4); in the unprocessed seeds, it ranged from 4.98% (Tpt17) to 4.55% (Tpt125). In the processed seeds, the fat content ranged from 18.91% (Tpt51) to 14.09% (Tp43) while in the unprocessed seeds, the values ranged from 19.01% (Tpt15) to 13.87% (Tpt3-B). The crude fiber in the processed samples ranged from 13.82% (Tpt6) to 10.40% (Tpt125) while in the unprocessed seeds, it ranged from 7.29% in Tpt51 to 4.83% in Tpt11. Carbohydrate content in the processed seeds ranged from 26.30% (Tpt3-B) to 20.94% (Tpt125) and 39.76% in Tpt3-B to 34.53% in Tpt18 in the unprocessed seeds. The tannin and phytate contents showed remarkably significant differences. In the tubers harvested, significant variation was observed in the parameters evaluated. Winged bean flour could be formulated into various meals for children and adults to reduce malnutrition in sub-Saharan Africa.

1. Introduction

Legumes are an essential source of oils and proteins [1]. Winged bean, *Psophocarpus tetragonolobus* (L.) DC., is primarily considered an orphan crop though it is known for its high yield potential and nutritional value when compared to soybean [2]. It is a lesser-known tropical legume grown in Papua New Guinea and Southeast Asia, mainly in Malaysia [1]. Winged bean seeds contain high dietary protein due to their amino-acid content, substantial protein bioavailability, and low levels of antinutritional factors [3]. Winged bean seeds are generating

unique research and commercial interest mainly due to their nutritional quality (high proteins and fatty oil content). Plant parts such as flowers, leaves, green pods, and tubers are also suitable for consumption [4].

Knowledge on the nutritional composition of winged bean seeds could help to decipher how the seeds can be used as a substitute for soybean which has similar features. Soybean proteins have been used extensively in food applications [5] and can therefore serve as a reference to evaluate new protein materials [6, 7]. In this study, seeds and tubers of selected accessions of winged bean were analyzed to evaluate their nutritional and antinutritional composition and document variability between accessions in response to processing. This study is part of the germplasm prebreeding program at the Genetic Resources Center, International Institute of Tropical Agriculture (IITA), aimed at increasing food security and dietary diversification in tropical agriculture.

2. Materials and Methods

Standard laboratory methods were used to analyze the seeds and tubers that were processed into flour as described by Alamu et al. [8] for proximate analysis (crude protein, fat, crude fiber, ash, moisture content, and carbohydrate), Adegunwa et al. [9] for tannin determination, and Wheeler and Ferrel [10] for phytic acid analysis. Field-harvested seeds were cleaned and slightly roasted under low heat until they were light brown in color. The roasted grains were coarse-milled and winnowed to remove seed coats. The decorticated grain was milled into fine powder and sieved for processed samples. The unprocessed samples were cleaned and milled until fine flour was obtained. The samples were labelled and stored in airtight containers at 4–6°C for analysis. The harvested tubers were peeled, rinsed with water, and oven-dried at 60°C. They were then milled, labelled, and packaged in airtight containers for analysis. The proximate and antinutrient analyses were conducted at the Food and Nutrition Sciences Laboratory (FNSL), IITA, Ibadan, Nigeria. Statistical Analysis Software (SAS, version 9.4) was used to determine the analysis of variance (ANOVA) of data obtained. Table 1 shows the passport data of the accessions used in this study.

Table 1: Twenty-five accessions of winged bean sourced from GRC, IITA.

Accession	Origin	Seed color
Tpt2	No passport data	Light brown
Tpt4	Costa Rica	Dark brown
Tpt6	Indonesia	Light brown
Tpt10	Sri Lanka	Brownish grey
Tpt11	Nigeria	Greyish orange
Tpt12	Sri Lanka	Brown
Tpt14	No passport data	Brown
Tpt15	No passport data	Dark brown
Tpt16	Indonesia	Greyish orange
Tpt17	Trinidad and Tobago	Light brown
Tpt18	No passport data	Brown
Tpt19	Nigeria	Dark brown
Tpt30	No passport data	Brownish orange
Tpt32	Liberia	Brown
Tpt33	No passport data	Light brown
Tpt42	No passport data	Reddish brown
Tpt43	Bangladesh	Dark brown
Tpt48	No passport data	Greyish yellow
Tpt51	Bangladesh	Greyish orange
Tpt53	Nigeria	Dark brown
Tpt125	No passport data	Light brown
Tpt126	Nigeria	Brown
Tpt154	No passport data	Greyish orange
Tpt15-4	No passport data	Reddish blond brownish orange
Tpt3-B	No passport data	Yellowish dark blond

3. Results

For processed seeds, the moisture content ranged from 8.51% (Tpt42) to 6.72% (Tpt6); in the unprocessed seeds, it was between 8.53% (Tpt53) and 3.76% (Tpt14). In the processed seeds, the values of ash ranged from Tpt126 (4.93%) to Tpt15-4 (4.45%); in the unprocessed seeds, it ranged from Tpt17 (4.98%) to Tpt125 (4.55%). In the processed seeds, the fat content was as follows: Tpt51 (18.91%), Tpt53 (18.79%), Tpt125 (18.66%), and the least was in Tpt43 (14.09%). In the unprocessed seeds, the values were Tpt15 (19.01%), Tpt10 (18.50%), Tpt14 (18.42%), and the least fat content was recorded in Tpt3-B (13.87%) (Tables 2 and 3).

Variations were observed in the crude protein content. In the processed seeds, Tpt17 had the highest content of 40.30%, followed by Tpt11 (39.72%), Tpt43 (39.35%), Tpt15-4 (39.21%), and Tpt4 (38.88); the lowest was recorded in Tpt48 (34.18%). In the unprocessed seeds, Tpt17 also recorded the highest crude protein content at 31.13%, followed by Tpt4 (31.02%), Tpt15-4 (30.84%), and Tpt42 (30.62%); the lowest was contained in Tpt125 (28.43%) (Table 2).

The crude fiber in the processed samples ranged from 13.82% (Tpt6) to 10.40% (Tpt125); in the unprocessed seeds, it ranged from 7.29% in Tpt51 to 4.83% in Tpt11. Relatively low levels of carbohydrate were present in winged bean, unlike African yam bean (*Sphenostylis stenocarpa*). In the processed seeds, the values obtained ranged from 26.30% (Tpt3-B) to 20.94% (Tpt125); the unprocessed seeds showed much higher values of carbohydrate than the processed samples from 39.76% in Tpt3-B to 34.53% in Tpt18. The tannin content varied among the accessions; in the processed samples, it ranged from 2.57% (Tpt51) to 1.81% (Tpt43) and in the unprocessed seeds, from 3.43% in Tpt32 to 1.36% in Tpt30 (Table 4). The phytate content also recorded differences, but these were not statistically significant. The highest content of tannins in the processed seeds was found in Tpt19 (9.38%) and the lowest in Tpt4 (3.78%); the values ranged from 9.96% in Tpt42 to 4.09% in Tpt19 (Table 5). Only moisture content, ash, fat, and crude protein levels were determined in the tubers harvested. The ash content also varied from 3.31% (Tpt154) to 1.10% (Tpt43) while the moisture content ranged from 7.81% in Tpt42 to 1.40% in Tpt43. Fat content ranged from 4.53% (Tpt33) to 0.21% (Tpt16) while the

Table 2: Proximate composition (mean ± standard deviation) of processed seeds of winged bean.

Accession	MC (%)	Ash (%)	Fat (%)	CP (%)	CF (%)	CHO (%)
Tpt06	6.72 ± 0.09	4.79 ± 0.02	17.65 ± 0.36	36.83 ± 0.14	13.82 ± 0.00	20.21 ± 0.29
Tpt10	6.84 ± 0.05	4.71 ± 0.09	16.07 ± 0.59	37.71 ± 0.03	11.13 ± 0.33	23.56 ± 1.00
Tpt11	6.92 ± 0.09	4.92 ± 0.00	14.91 ± 0.02	39.72 ± 0.35	10.79 ± 0.59	22.76 ± 0.17
Tpt12	6.89 ± 0.20	4.75 ± 0.03	17.38 ± 0.59	35.08 ± 0.13	9.88 ± 0.09	26.03 ± 0.33
Tpt125	8.38 ± 0.08	4.87 ± 0.00	18.66 ± 0.35	36.76 ± 0.05	10.4 ± 0.11	20.94 ± 0.60
Tpt126	8.10 ± 0.08	4.93 ± 0.06	15.01 ± 1.05	38.29 ± 0.34	11.47 ± 0.58	22.20 ± 1.94
Tpt14	6.78 ± 0.04	4.68 ± 0.01	15.59 ± 0.11	37.80 ± 0.22	11.64 ± 0.66	23.52 ± 0.61
Tpt15	6.75 ± 0.01	4.65 ± 0.03	15.14 ± 0.49	37.51 ± 0.16	10.62 ± 0.39	25.34 ± 1.06
Tpt15-4	8.34 ± 0.12	4.45 ± 0.59	15.71 ± 1.35	39.21 ± 0.10	11.02 ± 0.37	21.29 ± 0.41
Tpt16	6.77 ± 0.01	4.80 ± 0.04	16.16 ± 0.14	36.26 ± 0.08	10.73 ± 0.04	25.29 ± 0.04
Tpt17	6.97 ± 0.02	4.88 ± 0.06	16.21 ± 0.06	40.30 ± 0.02	10.60 ± 0.46	21.06 ± 0.47
Tpt18	6.72 ± 0.04	4.65 ± 0.03	17.12 ± 0.49	36.30 ± 0.08	10.87 ± 0.59	24.36 ± 0.19
Tpt19	8.10 ± 0.21	4.61 ± 0.06	16.63 ± 0.02	36.01 ± 0.47	10.96 ± 0.01	23.70 ± 0.58
Tpt2	6.74 ± 0.03	4.91 ± 0.08	17.65 ± 1.49	35.23 ± 0.22	11.75 ± 0.34	23.74 ± 1.04
Tpt3-B	7.69 ± 0.33	4.67 ± 0.17	17.60 ± 0.16	36.25 ± 0.13	7.50 ± 0.65	26.30 ± 0.14
TPt30	8.05 ± 0.04	4.78 ± 0.08	16.18 ± 0.21	36.24 ± 0.11	11.14 ± 0.43	23.63 ± 0.45
Tpt32	8.35 ± 0.16	4.73 ± 0.02	14.21 ± 0.22	38.70 ± 0.12	10.99 ± 0.11	23.05 ± 0.35
Tpt33	8.26 ± 0.02	4.60 ± 0.33	16.59 ± 0.10	36.81 ± 0.21	10.15 ± 0.18	23.60 ± 0.28
Tpt4	6.72 ± 0.16	4.75 ± 0.06	16.20 ± 0.60	38.88 ± 0.04	11.13 ± 0.29	22.34 ± 0.75
Tpt42	8.51 ± 0.33	4.54 ± 0.06	17.12 ± 1.56	36.48 ± 0.21	12.12 ± 0.82	21.24 ± 1.8
Tpt43	8.51 ± 0.03	4.60 ± 0.21	14.09 ± 0.10	39.35 ± 0.02	11.41 ± 0.33	22.06 ± 0.64
Tpt48	8.11 ± 0.09	4.61 ± 0.31	15.75 ± 0.37	34.18 ± 0.69	11.18 ± 0.30	26.19 ± 0.42
Tpt51	8.17 ± 0.04	4.63 ± 0.08	18.91 ± 1.91	36.24 ± 0.45	11.94 ± 1.39	20.12 ± 0.19
Tpt53	8.31 ± 0.10	4.63 ± 0.06	18.79 ± 0.47	34.33 ± 0.40	11.15 ± 0.19	22.80 ± 0.21
LSD	0.28	0.34	1.74	0.52	1.03	1.91
F value	59.73***	1.16^{ns}	5.09***	85.81***	8.97***	7.49***

Note. F values represent one-way ANOVA, degrees of freedom (df) = 24. *** $p < 0.0001$. MC = moisture content; CP = crude protein; CF = crude fiber; CHO = carbohydrate; ns = not significant; Tpt = tropical *Psophocarpus tetragonolobus*.

Table 3: Tannin and phytate concentration (mean ± standard deviation) of processed winged bean seeds.

Accession	Tannin (%)	Phytate (mm/100 g)
Tpt06	1.79 ± 0.40	5.05 ± 0.09
Tpt10	1.95 ± 0.07	6.73 ± 0.10
Tpt11	2.01 ± 0.29	8.07 ± 0.09
Tpt12	1.98 ± 0.03	8.70 ± 0.04
Tpt125	2.38 ± 0.14	8.56 ± 0.09
Tpt126	2.23 ± 0.47	9.26 ± 0.15
Tpt14	2.03 ± 0.06	8.17 ± 0.05
Tpt15	2.05 ± 0.16	7.57 ± 0.05
Tpt15-4	2.25 ± 0.04	8.09 ± 0.09
Tpt154	2.32 ± 0.18	5.74 ± 0.09
Tpt16	1.89 ± 0.03	8.71 ± 0.05
Tpt17	2.52 ± 0.12	6.73 ± 0.09
Tpt18	2.16 ± 0.11	9.24 ± 0.00
Tpt19	1.93 ± 0.11	9.38 ± 0.05
Tpt2	1.88 ± 0.24	5.28 ± 0.05
Tpt3-B	2.22 ± 0.50	7.05 ± 0.05
Tpt30	1.69 ± 0.02	9.25 ± 0.09
Tpt32	1.94 ± 0.12	9.36 ± 0.10
Tpt33	1.99 ± 0.18	8.32 ± 0.09
Tpt4	2.40 ± 0.43	3.78 ± 0.10
Tpt42	2.31 ± 0.18	7.01 ± 0.05
Tpt43	1.81 ± 0.29	7.60 ± 0.05
Tpt48	2.49 ± 0.00	6.73 ± 0.11
Tpt51	2.57 ± 0.23	8.89 ± 0.10
Tpt53	2.48 ± 0.14	9.16 ± 0.01
LSD	0.37	0.17
F value	4.47**	661.01***

Note. F values represent one-way ANOVA, degrees of freedom (df) = 24. *** $p < 0.0001$; ** $p < 0.001$. Tpt = tropical *Psophocarpus tetragonolobus*.

Table 4: Proximate composition (mean ± standard deviation) of unprocessed seeds of winged bean.

Accession	MC (%)	Ash (%)	Fat (%)	CP (%)	CF (%)	CHO (%)
Tpt06	4.74 ± 0.10	4.78 ± 0.04	17.76 ± 0.29	29.88 ± 0.22	5.49 ± 0.0	37.34 ± 0.15
Tpt10	4.63 ± 0.11	4.75 ± 0.02	18.50 ± 0.29	29.69 ± 0.10	5.43 ± 0.14	37.00 ± 0.44
Tpt11	4.75 ± 0.02	4.73 ± 0.15	18.28 ± 0.42	29.55 ± 0.93	4.83 ± 0.02	37.87 ± 0.66
Tpt12	5.45 ± 0.10	4.87 ± 0.02	18.35 ± 0.30	30.47 ± 0.10	5.18 ± 0.22	35.67 ± 0.53
Tpt125	7.19 ± 0.28	4.55 ± 0.08	15.76 ± 0.91	28.43 ± 0.52	6.26 ± 0.36	37.82 ± 1.43
Tpt126	7.37 ± 0.04	4.59 ± 0.00	17.84 ± 0.18	28.68 ± 0.01	6.29 ± 0.33	35.24 ± 0.21
Tpt14	3.76 ± 0.07	4.88 ± 0.01	18.42 ± 1.27	30.47 ± 0.05	5.93 ± 0.20	36.54 ± 1.06
Tpt15	4.05 ± 0.06	4.71 ± 0.01	19.01 ± 0.02	29.41 ± 0.06	5.71 ± 0.10	37.11 ± 0.11
Tpt15-4	5.34 ± 0.01	4.93 ± 0.05	17.75 ± 0.18	30.84 ± 0.32	5.78 ± 0.11	35.37 ± 0.29
Tpt16	4.62 ± 0.19	4.77 ± 0.09	18.27 ± 0.11	29.82 ± 0.55	3.09 ± 4.36	18.43 ± 26.06
Tpt17	4.07 ± 0.01	4.98 ± 0.15	18.33 ± 0.06	31.13 ± 0.93	SNE	SNE
Tpt18	5.97 ± 0.26	4.76 ± 0.17	18.14 ± 0.04	29.74 ± 1.07	6.86 ± 0.03	34.52 ± 1.06
Tpt19	7.45 ± 0.06	4.69 ± 0.04	15.99 ± 0.31	29.33 ± 0.26	4.61 ± 0.08	37.94 ± 0.02
Tpt2	5.12 ± 0.07	4.87 ± 0.02	17.81 ± 0.04	30.25 ± 0.10	5.70 ± 0.00	36.26 ± 0.18
Tpt3-B	6.55 ± 0.25	4.66 ± 0.06	13.87 ± 0.49	29.10 ± 0.37	6.06 ± 0.34	39.76 ± 0.33
TPt30	5.29 ± 0.01	4.75 ± 0.05	17.09 ± 0.56	29.72 ± 0.31	4.99 ± 0.03	38.16 ± 0.90
Tpt32	6.16 ± 0.00	4.72 ± 0.05	17.12 ± 0.24	29.47 ± 0.30	6.19 ± 0.37	36.35 ± 0.95
Tpt33	6.15 ± 0.14	4.72 ± 0.05	17.09 ± 0.55	29.48 ± 0.33	SNE	SNE
Tpt4	5.77 ± 0.05	4.96 ± 0.01	18.39 ± 0.02	31.02 ± 0.06	5.22 ± 0.08	34.63 ± 0.17
Tpt42	5.89 ± 0.02	4.90 ± 0.05	16.47 ± 0.61	30.61 ± 0.32	6.61 ± 0.60	35.52 ± 0.81
Tpt43	6.67 ± 0.07	4.63 ± 0.10	17.28 ± 0.13	28.93 ± 0.65	5.85 ± 0.01	36.64 ± 0.96
Tpt48	6.90 ± 0.03	4.57 ± 0.14	17.44 ± 0.43	28.54 ± 0.85	6.83 ± 0.46	35.71 ± 0.07
Tpt51	6.26 ± 0.03	4.69 ± 0.10	15.82 ± 0.12	29.34 ± 0.61	7.28 ± 0.07	36.61 ± 0.79
Tpt53	8.53 ± 0.08	4.64 ± 0.10	17.17 ± 0.70	29.00 ± 0.65	6.60 ± 0.32	34.06 ± 0.45
LSD	0.24	0.18	0.98	1.14	1.89	11.05
F value	223.09***	3.95**	11.48***	3.89**	5.19***	4.78**

Note. *F* values represent one-way ANOVA, degrees of freedom (df) = 24. *** $p < 0.0001$. MC = moisture content; CP = crude protein; CF = crude fiber; CHO = carbohydrate; Tpt = tropical *Psophocarpus tetragonolobus*; SNE = sample not enough.

Table 5: Tannin and phytate concentration (means ± standard deviation) of unprocessed seeds.

Accession	Tannin (%)	Phytate (mm/100 g)
Tpt06	1.76 ± 0.24	8.65 ± 0.14
Tpt10	2.55 ± 0.23	6.61 ± 0.09
Tpt11	2.55 ± 0.09	5.83 ± 0.05
Tpt12	2.33 ± 0.25	8.25 ± 0.05
Tpt125	1.92 ± 0.05	7.11 ± 0.05
Tpt126	1.92 ± 0.16	7.45 ± 0.05
Tpt14	2.41 ± 0.20	5.96 ± 0.05
Tpt15	2.76 ± 0.33	5.75 ± 0.05
Tpt15-4	1.82 ± 0.23	8.28 ± 0.10
Tpt154	1.92 ± 0.18	9.02 ± 0.10
Tpt16	2.56 ± 0.08	8.37 ± 0.05
Tpt17	2.94 ± 0.28	6.27 ± 0.00
Tpt18	2.45 ± 0.03	5.76 ± 0.05
Tpt19	1.39 ± 0.23	4.09 ± 0.14
Tpt2	2.25 ± 0.30	6.67 ± 0.09
Tpt3-B	2.70 ± 0.39	8.95 ± 0.00
Tpt30	1.36 ± 0.09	5.59 ± 0.09
Tpt32	3.43 ± 0.04	6.84 ± 0.05
Tpt33	2.81 ± 0.01	9.41 ± 0.09
Tpt4	2.52 ± 0.02	9.11 ± 0.03
Tpt42	1.96 ± 0.07	9.96 ± 0.10
Tpt43	2.59 ± 0.11	9.09 ± 0.10
Tpt48	1.71 ± 0.11	9.06 ± 0.05
Tpt51	2.89 ± 0.03	7.48 ± 0.09
Tpt53	1.72 ± 0.22	7.62 ± 0.09
LSD	0.38	0.16
F value	16.03***	772.36***

Notes. *F* values represent one-way ANOVA, degrees of freedom (df) = 24. *** $p < 0.0001$. Tpt = tropical *Psophocarpus tetragonolobus*.

Table 6: Percentage nutrient (mean ± standard deviation) of flours from winged bean tubers.

Accession	MC (%)	Ash (%)	Fat (%)	Protein (%)
Tpt10	6.83 ± 0.08	2.66 ± 0.03	0.53 ± 0.05	12.26 ± 0.28
Tpt11	7.13 ± 0.12	2.62 ± 0.16	0.49 ± 0.05	17.29 ± 0.29
Tpt12	7.79 ± 0.08	1.89 ± 0.36	0.90 ± 0.54	16.10 ± 0.03
Tpt125	5.76 ± 0.07	2.35 ± 0.04	0.53 ± 0.08	16.21 ± 0.06
Tpt126	5.94 ± 0.04	2.36 ± 0.02	0.23 ± 0.06	15.51 ± 0.13
Tpt15	7.11 ± 0.03	2.20 ± 0.05	0.38 ± 0.10	15.34 ± 0.18
Tpt15-4	6.96 ± 0.04	2.43 ± 0.02	0.31 ± 0.29	14.29 ± 0.33
Tpt154	4.67 ± 0.16	3.31 ± 0.03	0.34 ± 0.20	14.85 ± 0.02
Tpt16	6.16 ± 0.27	2.92 ± 0.01	0.43 ± 0.00	16.44 ± 0.32
Tpt18	7.67 ± 0.04	2.13 ± 0.06	0.41 ± 0.04	16.41 ± 0.14
Tpt19	6.99 ± 0.11	2.37 ± 0.00	0.45 ± 0.09	16.22 ± 0.23
Tpt2	6.63 ± 0.00	3.13 ± 0.00	0.45 ± 0.01	12.44 ± 0.02
Tpt3-B	7.81 ± 0.04	2.59 ± 0.00	0.51 ± 0.02	13.61 ± 0.30
Tpt30	7.23 ± 0.00	2.78 ± 0.03	1.17 ± 1.00	SNE
Tpt32	6.51 ± 0.00	2.54 ± 0.00	SNE	15.01 ± 0.57
Tpt33	6.96 ± 0.30	2.63 ± 0.10	4.53 ± 0.21	15.80 ± 0.88
Tpt4	6.82 ± 0.13	2.76 ± 0.02	0.54 ± 0.13	17.38 ± 0.10
Tpt42	7.69 ± 0.07	3.07 ± 0.00	4.38 ± 0.17	19.07 ± 0.02
Tpt43	2.80 ± 0.00	2.19 ± 0.00	SNE	SNE
Tpt48	6.10 ± 0.03	2.04 ± 0.06	1.04 ± 0.77	14.38 ± 0.16
Tpt51	5.45 ± 0.09	2.96 ± 0.00	0.55 ± 0.00	14.69 ± 0.34
Tpt53	5.26 ± 0.01	2.40 ± 0.00	0.51 ± 0.05	14.41 ± 0.53
Tpt6	6.70 ± 0.12	3.03 ± 0.05	0.49 ± 0.07	16.01 ± 0.04
LSD	0.45	0.18	0.57	0.72
F value	134.48***	19.4***	26.63***	54.89***

Notes. *F* values represent one-way ANOVA, degrees of freedom (df) = 22. *** $p < 0.0001$. MC = moisture content; SNE = sample not enough; Tpt = tropical *Psophocarpus tetragonolobus*.

protein content ranged from 19.07% (Tpt42) to 12.26% (Tpt10) (Table 6).

4. Discussion

In the present study, crude protein content ranged from 40.30% (Tpt17) to 38.88% (Tpt4) for processed seeds and 31.13% in Tpt17 to 28.43% (Tpt125) which are higher than results previously obtained for cowpea (22.5%), pigeon pea (22.4%), and lima beans (23.3%) but similar to the results for soybeans (35%) [11–13]. The values were also higher than the 14.70% [14] and 12.86% [15] previously reported for wheat flour. The differences may be linked to the geographical location of the germplasm collected since high nitrogen level in the soil can influence protein level [16]. The protein content of the flours suggests that they may be useful in food formulation systems which can be improved by blending with wheat or cowpea flour and used as composite flours. In the tubers, the result ranged from 19.07% (Tpt42) to 12.26% (Tpt10) which shows that winged bean contains a substantial amount of protein in its tubers. Our results are similar to the findings of Kantha and Erdman [17] who reported the protein content of winged beans to be in the range of 17–19%. We suggest that winged bean seed and tubers are potential sources of protein. The high protein content positions the crop to play a significant role in improving the nutritional status in tropical agriculture.

The values obtained for crude fat were higher (18.91% (Tpt51) to 14.09% (Tpt43)) in processed seeds and 19.01% (Tpt15) to 13.87% (Tpt3-B) in unprocessed seeds. These figures are higher than that reported by Singh et al. [18], who recorded a crude fat content of 0.47% in the fully mature seeds. They are however similar to those of previous studies that reported 15–20.4% [19] and those of other legumes such as chickpea (5.76–6.87%) as reported by Boye et al. [20]. The result obtained for the tubers (Table 5) ranged from 0.21 (Tpt16) to 4.53 (Tpt33). Due to its high thermal conductivity and oxidative features, winged bean oil is valuable as a frying medium when compared to soybean oil [21]. However, winged bean oil has more saturated fatty acids, thereby making it less preferred. A recent study of the physicochemical properties of winged bean oil found that fatty oil extraction using hexane, which is the most common industrial extraction process, agrees with all edible characteristics and fatty acid compositions [21]. In another study, winged bean oil was superior to soybean oil as a result of its high oxidative strength, solid fat content, and good thermal conductivity, thereby making it suitable for frying food [21].

Winged bean seeds are rich in carbohydrates. The unprocessed seeds contained higher carbohydrate content (39.76–34.53%) than the processed seeds (26.30–20.94%). These results are similar to those of previous studies that reported between 23 and 40% [4, 22] and 28.87 ± 0.45 in a study conducted by Wan Mohtar et al. [3], but low when compared to other studies involving cowpea and wheat flours, where values ranged from 57.35% to 83.60% [23] with wheat flour having the highest carbohydrate content (83.60%). In this study, the carbohydrate content of the flours cannot be compared to that of cowpea (57.17%) and wheat flours (74.22%) reported by Ahmed et al. [24]. Adukpo, Agbemafle [25] recorded a higher range of carbohydrate content (34.97 to 39.86%) for three soybean varieties. High carbohydrate content in legumes suggests that legumes can be used to manage protein-energy malnutrition since they have enough carbohydrate for energy such that the protein can be used for its primary function of body building and repair of worn tissues [26]. Carbohydrates are a good source of energy and are desired in high concentrations in breakfast meals and weaning formulas. The moderate carbohydrate content of winged bean flour can make it a good source of energy in breakfast formulations [26].

Crude fiber in the processed samples ranged from 13.82% (Tpt6) to 10.40% (Tpt125); in the unprocessed seeds, it ranged from 7.29% in Tpt51 to 4.83% in Tpt11. These results are consistent with that of Singh et al. [18] who recorded a crude fiber content of 12.65% in fully mature seeds and 2.76% in tubers. The values obtained for winged bean flour were higher than what Leach et al. [27] reported for brown rice flour (1.23%) and refined wheat flour (0.85%). The results obtained in this study were higher than the 0.85% reported by Leach et al. [27]. David et al. [23] reported that Asomdwee cowpea flour had the highest crude fiber content (3.21%). Chinma and Gernah [28] reported a crude fiber content of 8.19% for pigeon pea, 9.58% for cowpea, and 4.61% for mungbean flour. These

were all lower and slightly comparable to the crude fiber content obtained for the flours in this study. In human health, crude fiber helps to prevent heart diseases, colon cancer, and diabetes, among others. Therefore, it will be useful if winged bean flour is used in food formulations to help relieve constipation.

The moisture content of processed and unprocessed seeds differed significantly. Results showed that the moisture content of processed and unprocessed seeds was lower than the 9.20% reported by Olalekan and Bosede [29] for cowpea flours in Nigeria. In the tubers, it ranged between 1.4 (Tpt43) and 7.81% (Tpt3-B). The moisture content was within the acceptable limit of not more than 10% for long-term storage of flour [30]. It is influenced by type, variety, and storage condition of the material stored [31]. The low moisture content of winged bean flour may enhance its storage stability by preventing microbial growth and other biochemical reactions [30]. Sui et al. [32] reported a moisture content of 7.75% for wheat flour, which was within the values obtained in this study. This may explain why winged bean may have a longer shelf life and also confirms its usefulness in bakery products. According to Islam et al. [33] bakery products should have an adequate shelf life without any microbiological deterioration, and therefore the low moisture content of the soft-winged bean flour will in the end extend the shelf life of the final product.

The ash content of the flours ranged between 4.98% (Tpt17) and 4.55% (Tpt125) for unprocessed flour and from 4.93% (Tpt126) to 4.45% (Tpt15-4) in the processed flour. In the tubers, it ranged between 1.1% (Tpt43) and 3.31% (Tpt154) (Table 5). The ash content for winged bean flour in this study was higher than the 2.53% for mung bean flour, 2.53% for chickpea flour, 4.58% for pigeon pea, 4.73% for cowpea, and 3.25% for mucuna bean flour [29]. Ash content is an indication of the mineral content of food; it therefore suggests that winged bean flour could be a more important source of minerals than cowpea, mung bean, pigeon pea, and mucuna flours.

Despite all the positive nutrition benefits offered by winged bean, antinutritive factors (ANFs) also exist such as tannins, lectins, flatulence factors, phytoglutenins, saponins, and cyanogenic glycosides [34]. The use of moist heat or soaking has been shown to safely eliminate these substances without reduction in their nutritional composition. The presence of antinutrients in foods preparations particularly for children could hinder the efficient utilization and digestion of some nutrients and therefore reduce their bioavailability but may have beneficial effects on adults [2]. For example, research effort has yielded important milestone concerning trypsin, which act to hydrolyze proteins as part of the vertebrate digestion, and trypsin inhibitors, proteins that stop the action of trypsin whose action interfere with digestion. It has been suggested that trypsin inhibitors play a significant role in protecting plant tissues against bacterial proteases at the point where the pathogenic bacteria colonizes the host [35]. In addition, studies indicate the involvement of trypsin in defense against insects that suck the phloem sap and against bacteria that invade whenever there is wound [36]. Furthermore, in biomedical research, these modes of action have made trypsin and trypsin inhibitors significant part of molecular cell research, where they are strongly used in cell culture to remove cells from tissue culture plates [37, 38].

Tannins have been described to have cross-linked with proteins and caused a reduction in in vitro protein digestion of beans [39–42]. They have also been implicated in the inhibition of digestive enzymes, increased excretion of endogenous protein, and effect on digestive tract [39].

Phytate is another important antinutrient factor commonly found in legume seeds. It is an antioxidant that binds to some dietary minerals, interfering with their availability [34]. In this study, the phytate level ranged from 3.78 (Tpt4) to 9.38 (Tpt19) for processed seeds and from 4.09 (Tpt19) to 9.96 (Tpt42) in the unprocessed seeds. Phytate content in winged bean is estimated to be between 6.1 and 7.5 mg of phytate phosphorus per gram of beans, equal to that of soybean. Like many beans, winged bean possesses free phenolics, tannins, phytic acid, flatulence factors, saponins, and hydrogen cyanide. Some of these, especially tannins and phenolic compounds, nonspecifically inhibit enzyme activity and form a complex with food proteins, thus reducing their quality [43].

The tannin level ranges from 1.69 (Tpt30) to 2.57 (Tpt51) for processed seeds and from 1.36 (Tpt30) to 3.43 (Tpt32) in the unprocessed seeds, which is higher than the estimates of another study from 0.03 to 7.5 mg of beans [34]. Notwithstanding, the levels of phytate, etc., are not significant enough to cause adverse effects. Considering that most of these ANFs are destroyed by boiling or autoclaving [34], properly processed winged bean can be safely used as a major plant protein source. Overall, the proximate and antinutritional assessments of winged bean seeds and tubers were similar to those of previous studies of the crop and other similar crops [12, 19, 21, 44–47].

5. Conclusion

This study proved that there are variations in the nutritional and antinutritional values of winged bean. The protein content was very high and compares well with that of other legumes, and it could replace them in meals for protein enrichment. These protein levels indicate that winged bean, in particular, could be a replacement in various food formulations where soybean has been used. The crude fiber content of the seeds was higher than that of most other legumes, which indicated that the seeds are positioned as a functional food with health benefits associated with both soluble and insoluble fiber. We also observed that the antinutritional composition was low. The results showed that winged bean flour has the potential to be incorporated into food formulations as a functional ingredient.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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