Comparative nutritional and functional properties of selected underutilized legumes

^{*1}Soetan, K. O. and ²Adeola, A. A.

1. Department of Veterinary Physiology and Biochemistry, Faculty of Veterinary Medicine, University of Ibadan, Ibadan.

2. Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta.

*Corresponding author: kehinde.soetan@gmail.com; 08074437629

Abstract

Underutilized and neglected legumes have numerous nutritional potentials with great contributions to food security but they are usually excluded from research and development agenda. This study evaluates the nutritional and functional properties of six different underutilized and neglected legumes; Lima bean (LB) (*Phaseolus lunatus*) (2006-009), Bambara groundnut (BG) (*Vigna subterranea*) (TVSU- 1482), winged bean (WB) (*Psophocarpus tetragonolobus*) (Tpt-48), jack bean (JB) (*Canavalia ensiformis*) (Tce-4), sword bean (SB) (*Canavalia gladiata*) (Tcg-4) and African yam bean (AYB) (*Sphenostylis stenocarpa*) (TSS-95) from the Genetic Resources Unit (GRU), International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria. Nutritional and functional properties were evaluated using proximate composition, mineral analyses and functional properties like bulk density, water absorption capacity, oil absorption capacity, emulsion capacity and dispersibility. All the procedures were carried out using standard protocols. Statistical analysis was done using descriptive statistics. Results of proximate analysis showed that crude protein ranged from $18.88 \pm 0.15\%$ (WB) to $26.60 \pm 0.14\%$ (AYB), crude fat ranged from $1.84 \pm 0.02\%$ (JB) to $6.39 \pm 0.03\%$ (BG), crude fibre ranged from $3.70 \pm 0.00\%$ (AYB) to $5.04 \pm 0.03\%$ (SB), ash ranged from $3.10 \pm 0.14\%$ (AYB) to $4.66 \pm 0.02\%$ (LB), nitrogen free extract ranged from $55.60 \pm 0.04\%$ (SB) to $62.97 \pm 0.12\%$ (WB), moisture content ranged from $5.75 \pm 0.48\%$ (AYB) to $10.77 \pm 0.03\%$ (JB), dry matter ranged from $89.23 \pm 0.03\%$ (JB) to $94.25 \pm 0.488\%$ (AYB) and gross energy ranged from 4.39 ± 0.003 kcal/g (SB) to 4.66 ± 0.00 (BG). Mineral content results revealed that calcium varied from $0.14 \pm 0.000\%$ (LB) to $0.23 \pm 0.0003\%$ (AYB), phosphorus varied from $0.20 \pm 0.0001\%$ (AYB) to $0.38 \pm 0.00\%$ (BG), sodium varied from $0.12 \pm 0.00\%$ (LB and WB) to $0.35 \pm 0.0006\%$ (AYB), potassium varied from $0.69 \pm 0.00\%$ (LB) to $1.12 \pm 0.00\%$ (BG), magnesium varied from $0.15 \pm 0.0002\%$ (AYB) to $0.27 \pm 0.000\%$ (BG) and iron varied from 44.84 ± 0.03 (mg/g) (WB) to 80.98 ± 0.0007 (mg/g) (AYB). Results of functional properties showed that bulk density ranged from 0.45 ± 0.04 g/mL (WB) to 0.77 ± 0.08 g/mL (SB), water absorption capacity ranged from 168.33 ± 0.03 g/100g (LB) to 183.62 ± 0.01 g/100g (SB), oil absorption capacity ranged from 146.54 ± 0.02 g/100g (LB) to 161.55 ± 0.02 g/100g (JB), emulsion capacity ranged from 79.67 ± 0.02 g/100g (LB) to 89.46 ± 0.02 g/100g (SB) and dispersibility ranged from $81.0 \pm 1.41\%$ (SB) to $86.5 \pm 0.71\%$ (BG).

The study concluded that all the underutilized legumes have varying nutritional and functional properties, which should be exploited for nutritional benefits and industrial applications, as a solution to the problem of food shortage, especially in the developing countries.

Keywords: Underutilized legumes, nutritional, functional, food security

Introduction

Legumes belong to the Family *leguminacea* which are large and economically important family of plants (Gept *et al.*, 2005; Ojo, 2013). They include a large number of domesticated species harvested as crops for human and animal consumption. Leguminous plants play very critical roles in human and animal nutrition. They provide a significant amount of food in developing countries. Legumes *are the richest sources of plant proteins, providing about 10% of the total dietary requirements of the proteins world over* (Asif *et al.*, 2013). They are important sources of protein, fibre, complex carbohydrates (a strong case for glycemic index foods), iron, and zinc in the diet (Roba *et al.*, 2015). According to Roba *et al.* (2015) legumes, as protein source, are more desirable (cost-wise) than animal source foods in developing countries. In combination with cereal, legumes can supply the amino acids required for growth and development (Roba *et al.*, 2015). Consumption of legumes has been reported to reduce the incidence of coronary heart disease (Asif *et al.*, 2013). Legumes are utilised in many food formulations such as bakery products, bread, pasta, snack foods, soups, cereal bar filing, tortillas, meat, etc. (Asif *et al.*, 2013).

Global food security is being greatly threatened as a result of increasing over-dependence on a few major staple crops, leading to an alarming reduction in crop diversity and variability, especially the neglected and underutilized species (Ikhajiagbe and Mensah, 2012). However, variability is an important factor to consider in crop improvement programmes (Akinyosoye *et al.*, 2017). Neglected and underutilised species (NUS) are indigenous, relatively common, available, accessible, well-adapted, easy and cheap-to-produce crops (Okigbo, 1973; Padulosi *et al.*, 2003; Oniang'o *et al.*, 2006; Jaenicke

and Pasiecznik, 2009; Ojo *et al.*, 2016). NUS possess numerous nutritional potentials (Adewale and Aremu, 2013). Underutilized species are usually not recognised by policy makers probably because their economic value is not apparent (Stifel, 1990) and hence NUS are excluded from the research and development agenda of academic and research institutions. Underutilized crops are important as household food and they contribute significantly to food security (Naylor *et al.*, 2004; Oniang'o *et al.*, 2006). Lima bean (LB) (*Phaseolus lunatus*) belongs to the family leguminosae and is mostly cultivated in South America (Yellavila *et al.*, 2015). Lima beans are sometimes referred to as: haba beans, sugar beans, butter beans, Guffin beans, civet beans, Hibbert beans, Pallar beans, Sieva beans, Madagascar beans, and Burma beans (Yellavila *et al.*, 2015).

Bambara groundnut (BG) [*Voandzeia subterranean* (L) Thouars] originated in Africa origin used locally as a vegetable (Ayo *et al.*, 2014). According to Ayo *et al.* (2014) it is known by different names in Nigeria such as 'Gurjiya or Kwaruru' (Hausa tribe), 'Kwam' (Geom, Plateau State), 'Okpa' (Ibo tribe) and 'Epakuta' (Yoruba tribe). Bambara groundnut can be consumed in different forms (either at immature green or mature stages) as a vegetable and it is capable boosting food availability and improving malnutrition (Ayo *et al.*, 2014).

Winged bean (WB) (*Psophocarpus tetragonolobus*), an under-exploited legume, is a potential food source for the tropics (Amoo *et al.*, 2006). It is unique among leguminous crops in that, several parts of the plant: leaves, pods, seeds and tubers: are edible and rich in protein (Amoo *et al.*, 2006).

Jack bean (JB) (*Canavalia ensiformis*) is one of the under exploited tropical dry

beans which is widely distributed in Africa, Asia, the West Indies, Latin America and India (Marimuthu and Gurumoorthi, 2013). Raw Jack bean seed contains about 300 g kg⁻¹ protein and 600 g kg⁻¹ carbohydrates (Marimuthu and Gurumoorthi, 2013).

Sword bean (SB) (*Canavalia gladiata*) belongs to the Pea family: Fabaceae and originated either from southern Asia or Africa (Adebowale *et al.*, 2006). Sword bean possesses good agronomic properties which make it resilient to adverse climate change, and thus desirable for improving food and nutrition security in the tropics (Adebowale *et al.*, 2006).

African yam bean (AYB) (*Sphenostylis stenocarpa*), a lesser-known legume of the tropical and sub-tropical areas of the world, is gaining prominence in research (Obasi *et al.*, 2012). It has been claimed to be useful in the management of chronic diseases like diabetes, hypertension, and cardiovascular diseases due to its high dietary fibre content (Obasi *et al.*, 2012).

International Institute of Tropical Agriculture (IITA) in its pursuit of nourishing Africa continues to come up with different accessions of legumes, through its Genetic Resources Unit (GRU). The agronomic features of these new varieties of legumes have been determined. The literature is scanty on the chemical and functional properties of these new varieties. This paper therefore intends to provide information on the proximate composition, mineral constituents and functional properties of selected underutilized and lesser-known legumes.

Materials and methods

Source of the underutilized legumes

All the underutilized legumes; Lima bean (2006-009), bambara groundnut (TVSU-1482), winged bean (Tpt-48), jack bean (Tce-4), sword bean (Tcg-4) and African

yam bean (TSS-95) were obtained from the Genetic Resources Unit (GRU), International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria.

Preparation of flour samples

All the dried underutilized legume seeds were separately crushed into powdery forms with the use of an electric blender (Blender/Miller III, model MS-223, Taiwan, China).

Determination of proximate composition and energy content of flour samples of the legumes

The proximate composition of the legume samples (ash, crude fat (ether extract), crude fiber, moisture, dry matter and gross energy) were determined using (AOAC, 2000). The total nitrogen (N) was measured using macro Kjeldahl apparatus and crude protein content in the sample was calculated using the formula $N \times 6.25$. Crude fat (ether extract) content was determined using soxhlet apparatus.

Determination of mineral composition of flour samples of the legumes

The mineral analysis was performed with the method of AOAC (2000). The minerals tested were calcium (Ca), phosphorus (P), sodium (Na), potassium (K), magnesium (Mg) and iron (Fe). Na, K and Ca were determined by flame photometry while Mg, P, Fe and Cu were determined using atomic absorption spectroscopy.

Determination of functional properties of flour samples of the legumes

Bulk density was determined according to the method of Wang and Kinsella (1976). Water absorption capacity was determined by the method of Nwosu *et al.* (2010). Oil absorption capacity was determined according to the method of Onwuka (2005). Emulsifying capacity was determined according to the method of Coffman and Garcia (1977). Dispersibility was determined according to the method

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described by Kulkarni *et al.* (1991).

Results

The results of the proximate composition and gross energy content of the selected underutilized legumes are in Table 1.

Crude protein ranged from $18.88 \pm 0.15\%$ (WB) to $26.60 \pm 0.14\%$ (AYB), crude fat ranged from $1.84 \pm 0.02\%$ (JB) to $6.39 \pm 0.03\%$ (BG), crude fibre ranged from

$3.70 \pm 0.00\%$ (AYB) to $5.04 \pm 0.03\%$ (SB), ash ranged from $3.10 \pm 0.14\%$ (AYB) to $4.66 \pm 0.02\%$ (LB), nitrogen free extract ranged from $55.60 \pm 0.04\%$ (SB) to $62.97 \pm 0.12\%$ (WB), moisture content ranged from $5.75 \pm 0.48\%$ (AYB) to $10.77 \pm 0.03\%$ (JB), dry matter ranged from $89.23 \pm 0.03\%$ (JB) to $94.25 \pm 0.488\%$ (AYB) and gross energy ranged from 4.39 ± 0.003 kcal/g (SB) to 4.66 ± 0.00 (BG).

Table 1: Proximate composition (%) and gross energy (kcal/g) content of selected underutilized legumes

Varieties	Crude Protein	Crude fat	Crude fibre	Ash	Moisture	Dry Matter	Nitrogen free extract	Gross energy
Lima beans (2006-009)	19.98 ± 0.13	2.21 ± 0.03	4.75 ± 0.02	4.66 ± 0.02	8.77 ± 0.03	91.23 ± 0.03	59.64 ± 0.07	4.41 ± 0.00
Bambara groundnut (TVSU-1482)	21.14 ± 0.08	6.39 ± 0.03	4.54 ± 0.02	4.00 ± 0.04	7.81 ± 0.03	92.19 ± 0.03	56.13 ± 0.04	4.66 ± 0.00
Winged bean (Tpt-48)	18.88 ± 0.15	1.95 ± 0.02	3.87 ± 0.02	4.13 ± 0.02	8.23 ± 0.05	91.78 ± 0.05	62.97 ± 0.12	4.42 ± 0.00
Jack bean (Tce-4)	21.73 ± 0.08	1.84 ± 0.02	4.73 ± 0.02	3.99 ± 0.04	10.77 ± 0.03	89.23 ± 0.03	56.95 ± 0.06	4.41 ± 0.003
Sword bean (Tcg-4)	22.84 ± 0.08	2.10 ± 0.02	5.04 ± 0.03	4.27 ± 0.02	10.17 ± 0.02	89.84 ± 0.02	55.60 ± 0.04	4.39 ± 0.003
African yam bean (TSS-95)	26.60 ± 0.14	3.00 ± 0.14	3.70 ± 0.00	3.10 ± 0.14	5.75 ± 0.48	94.25 ± 0.48	57.85 ± 0.02	4.558 ± 0.01

Mean $\pm$ standard deviation

African yam bean. Source: Soetan (2017)

The Mineral constituents of the selected underutilized legumes are in Table 2. Calcium varied from $0.14 \pm 0.000\%$ (LB) to $0.23 \pm 0.0003\%$ (AYB), phosphorus varied from $0.20 \pm 0.0001\%$ (AYB) to $0.38 \pm 0.00\%$ (BG), sodium varied from $0.12 \pm 0.00\%$ (LB

and WB) to $0.35 \pm 0.0006\%$ (AYB), potassium varied from $0.69 \pm 0.00\%$ (LB) to $1.12 \pm 0.00\%$ (BG), magnesium varied from $0.15 \pm 0.0002\%$ (AYB) to $0.27 \pm 0.000\%$ (BG) and iron varied from 44.84 ± 0.03 (mg/g) (WB) to 80.98 ± 0.0007 (mg/g) (AYB).

Table 2: Mineral constituents of selected underutilized legumes

Varieties	% Calcium	% Phosphorus	% Sodium	% Potassium	% Magnesium	Iron (mg/g)
Lima bean (2006-009)	0.14 ± 0.00	0.36 ± 0.00	0.12 ± 0.000	0.69 ± 0.00	0.23 ± 0.00	48.95 ± 0.35
Bambara groundnut (TVSU-1482)	0.19 ± 0.00	0.38 ± 0.00	0.15 ± 0.00	1.12 ± 0.00	0.27 ± 0.00	57.95 ± 0.35
Winged bean (Tpt-48)	0.16 ± 0.00	0.36 ± 0.00	0.12 ± 0.00	0.88 ± 0.00	0.23 ± 0.00	44.84 ± 0.03
Jack bean (Tce-4)	0.17 ± 0.002	0.36 ± 0.002	0.13 ± 0.002	0.91 ± 0.002	0.25 ± 0.002	51.60 ± 0.14
Sword bean (Tcg-4)	0.16 ± 0.002	0.37 ± 0.002	0.13 ± 0.001	0.89 ± 0.002	0.24 ± 0.002	53.45 ± 0.21
African yam bean (TSS-95)	0.23 ± 0.0003	0.20 ± 0.0001	0.35 ± 0.0006	0.72 ± 0.0004	0.15 ± 0.000	80.98 ± 0.0007

Mean $\pm$ standard deviation

African yam bean. Source: Soetan (2017)

The functional properties of the selected underutilized legumes are in Table 3. Bulk density ranged from 0.45±0.04 g/mL (WB) to 0.77±0.08 g/mL (SB), water absorption capacity ranged from 168.33±0.03 g/100g (LB) to 183.62±0.01 g/100g (SB), oil

absorption capacity ranged from 146.54 ±0.02 g/100g (LB) to 161.55±0.02 g/100g (JB), emulsion capacity ranged from 79.67 ±0.02 g/100g (LB) to 89.46±0.02 g/100g (SB) and dispersibility ranged from 81.0±1.41% (SB) to 86.5±0.71% (BG).

Table 3: Functional properties of selected varieties of legumes

Varieties	Bulk density (g/mL)	Water absorption capacity (%)	Oil absorption capacity (%)	Emulsifying capacity (%)	Dispersibility (%)
Lima bean (2006-009)	0.53±0.04	168.33 ±0.03	146.54±0.02	79.67±0.02	85.0±1.41
Bambara groundnut (TVSU 1482)	0.46±0.04	176.30±0.02	153.70±0.04	83.75±0.02	86.5±0.71
Winged bean (Tpt-48)	0.45±0.04	171.46±0.01	149.25±0.02	81.56±0.02	83.5±2.12
Jack bean (Tce-4)	0.67±0.06	182.44±0.02	161.55±0.02	87.35±0.01	84.0±1.41
Sword bean (Tcg-4)	0.77±0.08	183.62±0.01	154.27±0.02	89.46±0.02	81.0±1.41
African yam bean (TSS-95)	0.67±0.06	179.35±0.02	158.66±0.02	85.79±0.03	85.0±1.41

Mean ± standard deviation

Bulk density (BD), Water absorption capacity (WAC), Oil absorption capacity (OAC), Emulsifying capacity (EC), Dispersibility (D)

Discussion

Proximate analysis is an index to the nutritive value of human foods and animal feeds. It is a scheme of analysis which involves the estimation of the main composition of foods with the use of procedures that enable a reasonably acceptable and rapid measurement of food fractions (James, 1996). The increasing knowledge and awareness on the nutritional and functional properties of different food constituents has led to a greater body of information that is needed for particular foods (James, 1996). There are variations in the proximate compositions of all the underutilized legumes analysed in this study. The proximate composition for the selected underutilized legumes in this study compared favourably with that of different varieties of cowpea (*Vigna unguiculata*), a conventional legume, whose crude proteins ranged from 21.2% to 30.6% (Swaminathan and Jain, 1973; Ene-Obong and Carnovale, 1992; Eromosele *et al.* 2008; Inobeme *et al.*, 2014), crude fat for

cowpea ranged between 1.7±0.1% to 4.21±0.36% (Ene-Obong and Carnovale, 1992; Giami, 1993; Inobeme *et al.*, 2014), crude fibre for cowpea ranged from 2.1±0.2% to 3.26±0.52% (Giami, 1993; Inobeme *et al.*, 2014), ash for cowpea ranged from 3.1±0.2% to 4.50±0.10% (Ene-Obong and Carnovale, 1992; Giami, 1993; Inobeme *et al.*, 2014), moisture content of cowpea ranged from 4.80±0.17% to 9.2±0.1% (Giami, 1993; Inobeme *et al.*, 2014), the nitrogen free extracts (carbohydrates) of cowpea ranged from 59.9±0.7% to 62.68±0.58% (Giami, 1993; Inobeme *et al.*, 2014). The nutritional and health importance of the proximate constituents of plants are well documented, proteins (Aremu *et al.*, 2006; Okeke and Elekwa, 2006; Okeke *et al.*, 2008), fats (Pamela *et al.*, 2005), fibre (Okeke and Adaku, 2009; Soetan and Olaiya, 2013), ash (Musa *et al.*, 2010), nitrogen free extracts (Okeke *et al.*, 2008), moisture (Ajayi and Adedire, 2007; Okeke and Adaku, 2009) and energy contents of foods (Omoyeni and Adeyeye, 2009).

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The minerals constituents of the selected underutilized legumes also compared favourably with that of cowpea (*Vigna unguiculata*). Inobeme *et al.*, (2014) reported calcium for cowpea to be within 194.12 ± 0.12 to 201.61 ± 0.53 (mg/100g), sodium (78.12 ± 0.85 to 81.70 ± 0.22 mg/100g), potassium (733.03 ± 0.34 to 741.15 ± 0.99 mg/100g), magnesium (190.22 ± 0.27 to 195.02 ± 0.10 mg/100g) and iron (9.80 ± 0.10 to 10.11 ± 0.9 mg/100g). However, Ene-Obong and Carnovale (1992) earlier reported different values, calcium (71.8 to 101 mg/100g), phosphorus (379 to 474 mg/100g), sodium (6.10 to 17.8 mg/100g), potassium (1271 to 1322 mg/100g) and iron (4.91 to 8.40 mg/100g). The health benefits of the mineral elements have been reported, calcium (Seidu *et al.*, 2014), phosphorus (Kalita *et al.*, 2007), sodium (Twum *et al.*, 2015), potassium (Murray *et al.* 2000), magnesium (Murray *et al.*, 2000) and iron ((Antia *et al.*, 2006). There is an increasing awareness of the role of mineral elements in human health and diseases (Gepts *et al.*, 2005).

Functional properties of protein foods are important considerations in consumer acceptance (Mune and Sogi, 2016). The variation in the functional properties of the samples may be an indication of the different nature of proteins in the various pulses. Bulk density indicates the porosity of food and has been reported to influence packaging requirement of flours (Etudaiye *et al.*, 2009). The bulk density reported for lima bean flour in this study was similar to the reported by Yellavila *et al.*, (2015) for five accessions of lima seeds from Ghana. The bulk densities of the samples of NUS in this study were similar to the values of 0.67 g/mL and 0.82 g/mL reported by Wani (2015) for red cowpea flour and black cowpea flour respectively. However, Chima *et al.*, (2008) reported lower range of

0.29-0.40 g/mL for certain varieties of cowpea. Food flour of higher bulk density would occupy less space per unit weight, resulting in lower packaging cost than flours with lower bulk density (Wani, 2015). Flour with low BD is preferred for complementary food preparation since it depicts less bulkiness and easy digestibility. BD is affected by the moisture content and particle size of food materials (Etudaiye *et al.*, 2009). Water absorption capacity gives an indication of the starch structure as starch polymers with loose structure have been reported to possess high WAC (Etudaiye *et al.*, 2009). The WAC capacity obtained for the samples were higher than 1.30 mL/g (130%) reported by Khalid and Elharadallou (2013) for cowpea flour but lower than the range of 1.89-2.15 mL/g (189-215%) obtained by Appiah *et al.* (2011) for certain cowpea varieties. High WAC of the flour samples may mean high swelling power, and high peak viscosity, indicating that flours from these pulses may be desirable in baked foods (Buckman *et al.*, 2017). High WAC enables bakers to conveniently manipulate the functional properties of doughs (Buckman *et al.*, 2017). Flours with high WAC have also been reported to possess more hydrophilic constituents such as polysaccharides (Yellavila *et al.*, 2015). The OAC which is an indication of the flavour retaining ability of food flour is higher among the samples investigated in this study than 1.04 mL/g (104%) reported by Khalid and Elharadallou (2013) for cowpea flour but lower than the range of 1.95-2.31 mL/g (195-231%) obtained by Appiah *et al.*, (2011) for certain cowpea varieties. The OAC is a reflection of the emulsifying capacity and the amount of oil that can be picked up by food material during frying (Falade and Okafor, 2015). Eltayeb *et al.* (2011) reported 281.35% and 252.27% respectively for WAC and OAC

of Bambara groundnut flour.

Emulsifying capacity measures the maximum amount of oil emulsified by protein in a given amount of flour. The emulsion capacity values obtained in this study were higher than the range (49.63-59.99%) reported by Yellavila *et al.* (2015) for some varieties of lima bean seed, but lower than the range reported by Eltayeb *et al.* (2011) for bambara flour. This may be due to the difference in methods of analysis. Khalid and Elharadallou (2013) reported a range of 72.73-173.60 g oil/g sample at a pH of 2-12 for the emulsifying power of cowpea flour. The difference in EC may also be due to surface hydrophobicity (HO), ligand binding, molecular flexibility, and structure stability of the proteins (Mune and Sogi, 2016). Formation and stabilization of emulsions is critical in many applications, such as chopped and comminuted meats, cake batters, coffee whiteners, milk, mayonnaise, salad dressings, bakery products, and frozen desserts (Mune and Sogi, 2016). Dispersibility has been positively correlated with the ability of flour to reconstitute in water (Adebawale *et al.*, 2005). The high dispersibility of the flour samples reinforced the earlier suggestion that they will be desirable in baked foods.

Conclusion

This study concluded that the selected underutilized legumes in this study; LB, BG, WB, JB, SB and AYB, all recorded good nutritional and functional proteins, many of which compared well with that of cowpea, a conventional legume. There is the need for more awareness and knowledge on other nutritional and health benefits of the underutilized legumes, so as to overcome the problem of food insecurity and nutritional-related diseases, especially in the developing countries.

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