Production, nutritional value and toxicity of *Kawal,* a fermented product from leaves of *Cassia obtusifolia* (L.): A review

Abstract

Cassia obtusifolia is a plant of the Fabaceae family. Its leaves are eaten as a vegetable in several African countries. In some African countries like Chad and Sudan, the leaves are processed by fermentation in a solid state, called in arabic *kawal*, which is eaten with cereal couscous. The present study is a literature review on the production of *kawal* and similar products. The production of *kawal* remains made by craftsmen. After crushing, the leaves are incubated in a buried jar for a period that varies from 14 to 30 days, sun-dried for 3 to 5 days and are ready for consumption. *Kawal* has several nutritional benefits. Fermentation increases protein content by 38% and especially essential amino acids methionine, threonine, valine, isoleucine, arginine, by 15, 51, 17, 113 and 3 % respectively. Also, during the processing of *kawal*, minerals content is improved, in particular calcium, magnesium and iron which increase by 98, 75 and 47% respectively. Concerning secondary metabolites, fermentation applied to *C. obtusifolia* leaves reduces the level of polyphenols, tannins and phytic acid by 20, 6 and 47% respectively. However, some studies on the effect of kawal on albino rats and chicken's growth have revealed signs of toxicity manifested through high level of serum transaminases and histopathology of the liver and kidneys. These data show that the fermentation of *C. obtusifolia* leaves improve nutritional value of this vegetable but does not considerably reduce secondary metabolites which could be considered as antinutrients and might be responsible of the toxicity in albino rats and chickens.

Keywords: *Cassia obtusifolia; kawal* production; fermented leafy products, nutritional value.

Introduction

Also known as *Senna obtusifolia* (L.), *Cassia obtusifolia* (L.) is an annual herbaceous plant of the family of Fabaceae, native of tropical America and southeastern United States, but now widespread in most tropical and warm temperate regions including those of Africa [1]. *C. obtusifolia* has a worldwide reputation because of its medicinal virtues, used to treat malaria, dizziness, high blood pressure, stomach aches, coughs, snakebites, urinary tract infections, conjunctivitis, photophobia, vision problem, swollen penis and dysmenorrhea in Korea, China, Japan, Benin, South Africa and Burkina Faso [2,3,4,5]. The leaves of *C. obtusifolia* are used as food by many people, more precisely as a vegetable in sauces, with different names such as *mbum ndur* in Wolof, *uulo* in Peul, *Tawassa* in Hausa, *Krikri* in Dioula, *Sigda* in Mossi and *Tasba* in northern Cameroon [5,6]. In Chad, *C. obtusifolia* is distributed both in the tropical and sahelian zone where it grows in fallow fields and nearby cattle routes [7]. In Chad, Sudan and other Central Africa country, the leaves are transformed by a process of solid-state fermentation in a fermented product called *kawal* to be eaten as a substitute for meat, fish or appetizing in sauces, but this technology remains made by craftsmen [8,9]. Kawal is a good source of protein (30.2 g/100g MS, calcium (3900 mg/100g MS), potassium (2000 mg/100g MS) and magnesium (600 mg/100g MS) [8]. Several forms of kawal have been studied, its technology described [10,11,12], and studies on the microorganisms involved in its fermentation carried out [13,14,15]. The objective of this review is to analyze the technology of production and the nutritional value of kawal.

1. Geographical distribution and African local names of *C. obtusifolia*

C. obtusifolia is a plant native to tropical America and the southeastern United States. Currently, it is found in the five continents with a pantropical distribution [1]. Irwin and Barnaby (1982) [ ] described it as a weed, invading pastures, plantations, orchards, occupying banks, lake edges, river beds, roadsides and open spaces around farms and dwellings. The plant is widespread throughout tropical Africa with exception of Madagascar [17]. In Sudan, it is mainly found in

clay plains and wetlands, in the central and southern regions [18]. In Chad, *C. obtusifolia* is distributed in both the tropical and Sahelian zones where it grows in fallow fields and nearby cattle routes. A ruderal plant with a nitrophilic tendency, *C. obtusifolia* is found in southern Chad in the Sudano-Guinean zone, in the north in Ennedi and west of Tibesti [7].

Cassia obtusifolia is synonym of *Cassia tora* and *Senna obtusifolia* [19]. In Africa, *C. obtusifolia* is called *mbum ndur* in Wolof, *jàmba sero* in Manding, *uulo* in Peul, *Tawassa* in Hausa, *Krikri* in Dioula, *Sigda* in Mossi, *Tasba* in northern Cameroon *Sooula* in Boko, *Tikpahunkpadi* in Gourmantché [20,6,2,5]. The common names of *C. obtusifolia* are: *Cassia fétide, Casse feride, Casse puante, Séné, Pistache marron* in French; *Siklepod, African foetid cassia, Low cassia* in English; *Ashraq, Tukhme, Panwar* in Arabic [2,19].

2. Botanical Description of C. obtusifolia

C. obtusifolia is an annual herb belonging to the Fabaceae family (Figure 1,2). Its stems are erect, 0.5 to 2 m high, branched, green, round and glabrous. The leaves are alternate, compound and pinnate. They are made up of three pairs of leaflets. The leaflets are elliptical to obovate with rounded tips. They are 2 - 7 cm long, with the terminal pair being the largest [1]. On the rachis, between the first two leaflets, a large gland is inserted. Two linear and falciform stipules of about 15 mm long are presents at the base of the rachis [7,18]. One or two inflorescences are borne on peduncles 3 - 4 mm long inserted in the axils of the leaves. The flowers consist of five unequals apex-rounded yellow petals and unequal elliptical sepals [21]. The fruits are long-beaked pods measuring 3 mm wide and 10-15 cm long [7].

3. Uses of C. obtusifolia

Cassia obtusifolia is an economic plant which has wide range of local and international uses in food, feed, medicine, gum, paper and textile industries. It is a source of foreign exchange and employment in agriculture, from *C. obtusifolia* seeds collection, seeds treatment, land

preparation, planting, plant management, harvesting, and seed value change, transportation to industrial processing of the *C. obtusifolia* plant for human and animal uses [21].

3.1. *C. obtusifolia* in traditional medicine

C. obtusifolia is an important medicinal plant with multiple uses. The seeds are used to treat eyes problems, they lower cholesterol and blood pressure, prevent the formation of atherosclerotic plaques in the arterial wall and they have laxative and antibacterial effects [23]. Roasted and boiled in the form of tea, they are used against diarrhea, tremors and urinary tract infections [24,20]. Doughari et *al* [24] showed that leaf extracts of *C. obtusifolia* possess a broad spectrum of activity against gram-positive bacteria, gram-negative bacteria and fungi. The leaves, roots, stems and seeds are used to cure a wide range of diseases, especially in traditional Chinese medicine with significant antioxidant and anti-inflammatory properties [25]. The plant is used for skin diseases, ring worm and its antimicrobial activity in Inde [19]. It used in several African countries in traditional medicine. In Burkina Faso the leaves are used against stomachache, malaria, arterial hypertension, jaundice and the stems against cough, jaundice, malaria [5]. In South Africa, *C. obtusifolia* roots are boiled and the mixture drank for treating swollen penis, stomach problems or dysmenorrhea [4]. In Nigeria, the seeds, leaves and roots of the plant are used by traditional medicine practitioners as mild laxative drugs for children and pregnant women [26,17]. In Benin it is used by communities to heal malaria [2].

The use of *C. obtusifolia* in traditional medicine is due to the presence of several phytoconstituents such as anthraquinones, naphthopyrones, xanthones, lactones, sterols, triterpenoids, saponins, tannins, alkaloids and flavonoids which are responsible for the following pharmacological effects : anti-inflammatory, anti-allergic, antiseptic, anthelmintic, antipyretic, diuretic, carminative, purgative, antidiabetic, antimicrobial, antioxidant, hepatoprotective, neuroprotective, anti-Alzheimer's disease, antiplatelet aggregation, larvicidal activities and insecticidal effect [26, 19, 27,25].

3.2. *C. obtusifolia* as food

The seeds of *C. obtusifolia*, although famous in traditional medicine, also play an important role in feeding. Roasted and ground, they are used as a coffee substitute in China [28]. Additionally, they are a source of cassia gum, a food additive commonly used as a thickener [24]. The young tender leaves of *C. obtusifolia* used as vegetable in Cameroun, Niger, Nigeria, Ghana, Ethiopia, Senegal, Benin and Burkina Faso [26,2,29,30,5]. The picking season of the leaves of *C. obtusifolia* is from July to October [5]. The plant is cultivated in home for leaves consumption in several countries including Senegal, Ghana, Cameroon and Ethiopia [26]. In Chad and other parts of Africa, the leaves are made into kawal (Figure 3) through a solid-state fermentation process and used as a meat substitute in sauces eaten with cereal couscous [31,15].

3.3. Other uses of *C. obtusifolia*

In Sahelian zone, leaves of *C. obtusifolia* are used as well as other parts of the species. Hence, dry stems are used in the making of seccos, hut roofs and granaries; they are also used as fertilizer in the fields [32]. In Burkina Faso the stems of *C. obtusifolia* are used as firewood or skewers [5]. In Nigeria the plant is also used as fodder for animals [29]. Floured seeds have nematocidal properties when incorporated into soil at 5% [33].

4. Technology of production of Kawal

Dirar [10] was one of the first authors to describe kawal production technology in the literature. Its description is in accordance with the usual fermentation procedure used by people of Dar-four in Sudan, description known as the best in literature. According to this procedure, the leaves are harvested at the stage of flowering and fruiting. They are cleared of all impurities such as flower petals and leaves damaged by insects, caterpillars, and leaves of other plants. The leaves are then pounded in a wooden mortar into a paste without losing their juice. The paste is packed in an earthenware jar (with a capacity of about 30 L) previously buried in a hole

dug in a cool and shady ground. Only the neck of the jug remains above the ground level. The surface of the dough is covered with a pile of folded sorghum leaves, held together by the weight of washed stones. The opening of the jar (called *zeer*) is covered with a suitable utensil and sealed with the mud. After every three days, the *zeer* is opened, the sorghum leaves which have dried up are removed and the paste mixed and triturated by using hand. The dough is then repackaged, old dried sorghum leaves replaced by the fresh ones and the *zeer* resealed. After a 15-day incubation period, the matured kawal is removed, reduced into many small balls that are sun-dried on a rack or raised platform for 5 days. At this stage, the dried kawal is ready for consumption. A similar description was made by Mbaiguinam *et al.* [12] about kawal produced in Chad. But Suliman *et al.* [11] in Sudan presented a different process. In the description of the latter one, the absence of grinding and regular mixing every three days during incubation are registered. Also, cleanings of the dough were quoted consisting in removing the fibers at the end of incubation as well as the duration of the fermentation which extends to approximately three weeks. More recently, Abakar *et al.* [31] described this process in Chad and indicated an incubation period ranging from three to four weeks. In general, the duration of fermentation varies between 14 and 25 days and depends on the local conditions, the producer and the organoleptic quality of the desired final product. Processing techniques used in kawal fermentation and procedures differ according to localities, environmental factors, types of equipment and their availability. Abakar *et al.* [31] reported the use of plastic bags as incubators instead of earthenware jars in some localities in Chad or Sudan.

The container used during fermentation can be different. In Chad, Abakar *et al.* [31] cited the plastic bag, while in Sudan, Nuha *et al.* [8] described a rather particular preparation of the jar. Indeed, the inside of the jar is coated with a type of very sticky mud of the same type used for pottery. The sides and bottom of the jar are beaten firmly with a stone. Then the inside is rubbed with a mucilaginous substance, usually okra (*Abelmoschus esculentus*), or a wild plant called

abadeib (*Ceratotheca sesamoïdes*), which prevents the mixing of the kawal with the earth. All the descriptions made by authors have not considered all aspects of the technology, in particular practices around the process of fermentation carried out by the producers, and this could be a subject of research.

The production technology of kawal which is done under natural conditions is underpinned by microorganisms responsible for the fermentation of *C. obtusifolia* leaves. According to the work of Ibrahim *et al.* [15], several colonies of bacteria were isolated from kawal. A total of 51 colonies of bacteria were isolated and divided in three groups. The largest group exhibits rod-shaped, gram (-) and catalase (-) / (+), motile, and spore-forming bacteria. These characteristics indicate that the isolates belonged to the strain *Bacillus* spp. Similar results were found by Dirar et *al*. [13] and Abakar *et al.* [14] who reported that *Bacillus* spp is the most dominant group of microorganisms in fermented kawal. The second group of isolates consists of smooth, gram (+), catalase (+) and oxidase (+), spore-forming cocci with nitrate reductase activity, identified as *Staphylococcus scuiri* spp. While the last small group of isolates are characterized by smooth, gram (+), immobile, non-spore-forming rod-shaped bacteria with an ability to ferment different starches and sugars. It has been identified as *Lactobacillus plantarum* spp. As for yeasts and molds, they were negligible in most of the samples that were analyzed. Abakar *et al.* [14] also isolated species of lactic acid bacteria from kawal. They reported that their numbers varied between samples.

Biochemical and molecular characterization studies of Bacillus strains isolated from kawal sample showed a high diversity of species within the genus *Bacillus.* These species are: *B. subtilis, B. licheniformis, B. pumilus and B. amyloliquefaciens*; however, the dominant species in the kawal is *Bacillus subtilis* [14]. All researchers who have worked on kawal microorganisms agree that *B. subtilis* isolated from kawal of very diverse origins is the most important strain involved in its fermentation process, then might be used as a culture starter in

the controlled fermentation of *C. obtusifolia* leaves for large-scale production [15,14, 13]. Among the species of bacteria found in kawal, *L. plantarum* constitutes only a relatively small proportion of the population, as expected under the pH conditions of kawal fermentation. Indeed, throughout the fermentation, the pH does not significantly vary, and remains between 6 and 7. This finding contrasts with observations made during the fermentation of many other plant substrates, where the accumulation of acidic products can cause the pH to drop to values lower than 3, conditions which favor the growth of aciduric bacteria, especially *Lactobacillus* spp. The pH value during fermentation of kawal is a feature likely attributable to the buffering capacity provided by the high calcium content of *C. obtusifolia* leaves [13].

Bacteria, as well as yeasts and molds, could originate from the natural microflora of the leaves, the surface of the fermentation tank and the handling of the product [14,13]. Frequent mixing gives rise to micro-aerophilic conditions during fermentation that ensure the predominance of facultative anaerobes, as opposed to obligate anaerobes, and could explain how the poorly fermentative yeast, *Candida krusei*, was found in the process. In exceptional cases, a large population of *Pseudomonas putida*, an obligate aerobic bacterium, has been found in certain samples whose chemical composition is atypical. The presence of these bacteria could indicate faulty fermentation.

5. Effect of technology on the nutritional value of *C. obtusifolia* leaves

The effect of processing in kawal on the nutritional value of *C. obtusifolia* leaves is shown in Table 1. The leaves of *C. obtusifolia* are a good source of protein. Its protein content has been assessed in Sudan, Chad, Cameroon and Nigeria; it ranges from 19.77 to 25.44 g/100g dry weight (DW) [13,12,6,8, 34]. Most authors agree that fermentation improves the protein content of the leaves. The kawal production technology improves the protein content of *C. obtusifolia* leaves which increases by 7.8% [13] to 38,1% [8] in the kawal.

As with proteins, fermentation of *C. obtusifolia* leaves helps to increase the amount of lipids in the kawal by 3.97 - 4.12% [8]. This increase can be attributed to the synthesis of lipid bacteria and fungi. Unlike proteins and lipids, the production process of kawal contributes to the reduction of total sugar and fiber content. Fermentation of *C. obtusifolia* leaves reduces crude fiber levels from 13.5 to 12.1 g/100g DW [13]. These small changes mean that this fraction is probably not involved in the process as a substrate [13]. The total sugar contents have been reduced from 36.41 to 18.75 g/100g DW [35]. This important reduction of sugar contents is probably due to microorganism's activity during fermentation. Microorganisms use carbohydrates as an energy source and produced carbon dioxide as a by-production [8].

Kawal production technology reduces the amounts of secondary metabolites. Algadi and Yousif [37] have shown that fermentation significantly reduces the levels of total polyphenols, tannins and phytic acid by 20%, 6% and 47% respectively. The reduction of the polyphenols contents during the fermentation of food is due to the presence of enzymes responsible of the phenolic compounds hydrolysis such as the polyphenols oxidase, peroxidases, laccases [38]. These enzymes which may be present in food stuff or produce by the microorganisms during fermentation. Phytate is one of the most abundant organic phosphorous compounds in nature. His important loss is due to the action of microorganisms during fermentation. These microorganisms hydrolyze phytate into inositol and orthophosphate [39].

C. obtusifolia leaves have an ash content of 10.4–12.6 g/100g DW while kawal has an ash content ranging from 18.0–19.7 g/100g DW [13,6,12,8,14,34]. Already the amounts of ash in the dried leaves are high. This can be attributed to the high level of calcium (3006 mg/100g DW) and potassium (1703 mg/100g DW) as presented in Table 2. The production technology increases the mineral content in kawal. The minerals with the highest values are calcium (5974 mg/100g DW) whose rate has almost doubled, potassium (2054 mg/100g DW), magnesium

(627 mg/100g DW) and phosphorus (593 mg/100g DW). The kawal contains the main minerals elements necessary for the human body.

The traditional process of producing kawal relatively modifies the level of amino acids. In general, alanine and methionine content increases while the amount of aspartic acid, glutamic acid, lysine, arginine and threonine decreases [9,35,12,13]. Table 3 presents the amino acid composition of *C. obtusifolia* leaves and kawal.

The amino acid level largely covers the needs for essential amino acids (lysine, histidine, threonine, tyrosine, leucine, isoleucine, phenylalanine, and valine) and semi-essential for humans and limiting cysteine (semi-essential amino acids). As for sulfur amino acids, they are not strictly limited in kawal. On one hand, methionine is the amino acid which records the lowest concentration in unfermented leaves but its concentration increases in fermented leaves; on the other hand, arginine which is an essential amino acid for the growth of children, is present in sufficient quantity in fermented and unfermented leaves, although fermentation slightly reduces its value [14,12]. It therefore emerges from this work that the fermented *C. obtusifolia* leaves are well balanced in essential amino acids, and in semi-essential amino acids with sufficient concentrations according to the amino acid requirements for different age groups of FAO and WHO [14,36,12]. Kawal may also be a good source of vitamins. However, no study has explored vitamins content of kawal, and this could be an interesting subject of research.

The microorganisms responsible for the fermentation of the leaves of *C. obtusifolia* are involved in the production of the volatile substances present in the kawal. The work of Mbaïguinam *et al.* [12] showed that volatile substances are essentially composed of aliphatic acids (45.43%). The corresponding esters represent 6%, while the phenolic compounds represent 32%. They contain high quantities of hexanoic acid (27%) and butyric acid (10%). According to these authors, the latter compound could be identified as responsible of goat-like and cheese-like odor

of the fermented leaves of *C. obtusifolia*. The amount of other aliphatic acids such as 3-methylbutyric (5.48%) and 2-methylbutyric (2.48%) seems to be notable. These compounds exhale a fruity odor. The presence of p-methylphenol (13%) and p-ethylphenol (17.21%) suggests the attack of the main phenolic constituents of the raw materials by the yeast during the semi-anaerobic fermentation. The level of volatile substances varies during fermentation and drying. According to Dirar [13], the amount of volatile substance rises sharply from the 4th day of fermentation and stabilizes at around the 7th day until the end of fermentation. During drying, this rate decreases to more than a third. The volume of *n* -butyric acid follows roughly the same pattern: it rises sharply on the 4th day of fermentation, stabilizes on the 7th day and drops sharply when drying to more than half. On the other hand, n-propionic and isobutyric acids show a slight decrease during drying.

The influence of production technology has been studied in a biochemical point of view and has concerned nutrients, minerals, antinutrients and volatile substances. These studies were not extended to sensory analyzes to determine the organoleptic characteristics of kawal.

6. Effect of technology products on growth and toxicity in animals

Fermented leaves of *C. obtusifolia* have been studied for growth in animals, in albino rats and chickens. In Sudan, Yagi *et al.* [40] studied the toxic effects of incorporating 2% and 10% of kawal into the diet of rats. The results showed that the red blood cell count was comparable to the control, however, the hemoglobin and hematocrit values decreased compared to the control. A remarkable increase was observed in the activities of glutamate pyruvate dehydrogenase and creatinine of the rats having received the kawal in incorporation either at 2% or at 10%. This increase was like those given the dried leaves of *C. obtusifolia.* A Similar pattern was observed for protein, albumin and globulin concentrations. Increased of transaminases and creatinine are a sign of toxicity. If both fermented and unfermented leaves show induced toxicity in animals, this suggests that the fermentation did not sufficiently reduce secondary metabolites.

The results of studies by Yagi *et al.* [40] also showed that consumption of kawal caused significant histopathological damage in rats. Damage was detectable in the intestine, liver, and kidneys when rats were fed 2% or 10% kawal. The lesions were proportional to the duration of the feeding period. This same observation is made for dried leaves, however, in rats fed 2% kawal the histopathological changes in the liver were less impressive than those caused by 2% dried leaves of *C. obtusifolia*. The remarkable increase in the level of serum creatinine reflects the toxic damage caused by kawal to the kidneys. Kawal caused more extensive kidney damage than that caused by dried leaves of *C. obtusifolia*. Similar observations were made by Suliman *et al.* [11] in an experiment using chicken as animal material. These authors reported that kawal induces the reduction of the concentrations of total proteins, albumin and globulin while it increases the concentrations of transaminases ALAT and ASAT. They also reported decrease in hematocrit volume and hemoglobin concentration. Therefore, the affected organs were mainly the kidneys, intestine, liver, heart, lungs, kidneys and spleen. The severity of the lesions increased with the quantities of kawal incorporated. The liver is the seat of plasma protein synthesis. The reduction in the concentration of total proteins as well as the increase in transaminases testify to a dysfunction of the liver function. This is confirmed by histopathological studies of the liver and other organs. This shows that there is severe toxicity which cannot be justified only by presence of secondary metabolites. Such toxicity could be due to the presence of mycotoxins, bacterial toxins, biogenic amines, cyanogenic glycosides and ammonia which are produced during the fermentation process [41,42].

Other experiments feeding rats with fermented leaves of *C. obtusifolia* gave different results than those reported above. It should be noted that the fermentation did not take place under the same conditions as those of kawal. Indeed, in Nigeria, Augustine *et al.* [43] fed albino rats with 20% *C. obtusifolia leaves* that had undergone the following treatments: sun-dried, boiled, fermented fresh, boiled and fermented. Rats fed with the leafless control diet of *C. obtusifolia*

showed higher food consumption. These observed effects could be due to the odor of processed *C. obtusifolia leaves* in the feed. Weight gain was higher in the group fed fermented leaves compared to sun-dried leaves. This could be due to the decrease of anti-nutritional factors level caused by the fermentation. Rats fed with the fermented leaf diet showed that levels of red blood cells, hemoglobin and hematocrit were within the normal ranges of 6-8 g/dL, 11-19.2 g/dL and 36 to 54% respectively unlike those fed with the sun-dried leaves whose levels of red blood cells, hemoglobin and hematocrit were the lowest. The concentrations of white blood cells as well as other parameters such that proteins and globulins, serum electrolytes, creatinine, urea, alkaline phosphatase, alanine aminotransferase (ALT), aspartate aminotransferase (AST) and bilirubin were analyzed. The results were within normal ranges for all diets. This allowed the authors to conclude that the inclusion of 20% fermented leaves of *C. obtusifolia* had no adverse effects on the immune system, liver and kidneys of rats. The difference in the results of Augustine *et al.* [43] in Nigeria with those of Yagi *et al.* [40] as well as Suliman *et al.* [11] in Sudan would be due to the fermentation conditions. Augustine *et al.* [43] performed a 9-day fermentation under laboratory conditions, while the authors from Sudan had based their studies on the kawal whose fermentation followed different stages of the technological production process. The number of days of production of the kawal (14 to 25 days) as well as the regular mixing every three days are enough to create this difference. In addition, all the authors who have described the kawal production technology specify that the harvest was made at the end of the rainy season and at the flowering and fruiting stage [31,8,12,11,13,10]. Probably the age of the plant at the time of picking constitutes an essential element in the difference of the biochemical composition of the final product. The toxic effects of kawal presented by Yagi *et al.* [40] as well as Suliman *et al.* [11] could be due to the presence of ammonia and biogenic amines, in particular histamine in the kawal [35,11,13]. Data from these studies on the effects of the influence of kawal production technology in animals are not enough. In addition, in Chad,

no study on the capacities of kawal to induce growth and/or toxicity on animals has not been carried out.

Conclusion

Kawal is a traditional product used as an ingredient in sauces in Chad and some African countries. In this review, it appears that the technology greatly influences the biochemical and nutritional quality of kawal by improving the protein and mineral content on one hand and reducing the level of secondary metabolites on the other. Indeed, there are variants of this technology which have not been investigated. Besides, there are aspects of kawal that have not been subjected to studies, notably the practices during production by the producers and the sensory analysis of kawal.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Availability of data and materials

All data or analyses during this study are included in this published article.

Code availability

Not applicable.

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Table 1: Effect of technology of production of kawal on nutritional composition (g/100g DW) of *C. obtusifolia* leaves [13, 35, 37]

	Raw leaves	**Fermented leaves**
Proteins	21 – 25	26 – 30
Lipids	2 – 3	3 – 4
Carbohydrate	28 – 36	18 – 22
Ash	12 – 12	18 – 19
Fiber	13 – 24	12 – 21
Total polyphenols	4	3
Tannins	2	2
Phytates	649 (mg/100g)	340 (mg/100g)

Table 2: Effect of fermentation on mineral content of *C. obtusifolia* leaves (mg/100g DW) [35]

Minerals	Raw leaves	Fermented leaves	Variation (%)
Na	133	176	32.0
K	1703	2054	20.5
Ca	3006	5973	98.7
Mg	357	626	75.1
P	414	593	43.1
Fe	41	61	47.8
Mn	14	17	16.0
Cu	4	5	4.3
Zn	2	6	172.4

Table 3: Fermentation effect of *C. obtusifolia* leaves on amino acid content [9].

Amino acids	Raw leaves (mg/100g dry weight)	Fermented leaves (mg/100g dry weight)	Variation (%)	Requirement (mg/kg weight Adult/Day) [36]
Threonine	137	353	61.2	750
Valine	173	476	63.6	1300
cystine	7	-	-	-
Methionine	73	157	53.5	500
Isoleucine	91	300	69.7	1000
Leucine	208	538	61.3	1950
Tyrosine	122	273	55.3	1250 (Tyr+ Phe)
Phenylalanine	149	397	62.5	
Lysine	205	456	55.0	1500
Histidine	79	191	58.6	500
Arginine	136	121	12.4	
Aspartic Acid	444	697	36.3	
Serine	130	340	61.7	
Glutamic Acid	375	1163	67.7	
Proline	632	1260	49.8	
Glycine	135	410	67.1	
Alanine	169	499	66.1	