

Technology and Biochemical Changes Associated with the Production of Zamne: A Traditional Food of *Senegalia macrostachya* Seeds from Western Africa

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Abstract

Technology and nutritional composition of zamne a traditional food of *Senegalia macrostachya* seeds from western Africa were studied in different production sites with the aim to establish the flow diagrams and evaluate the effect of the processing on its biochemical composition. Result showed a diversity of the processing methods according to the locality. The process included mainly successive cleaning of seeds, boiling for about 3-6 h, softening with alkalinizing ash leachate. The raw seeds were composed of 26.56 ± 1.24% of crude proteins, 40.08 ± 0.49% of crude lipids, 28.02 ± 0.05% of carbohydrates and 16.19 ± 0.16% of fibres on dry matter basis. For the ready to eat zamne, the moisture content varied from 79.54 ± 0.1 to 81.27 ± 0.2%, ash content from 4.95 ± 0.06 to 9.58 ± 0.13%; total carbohydrate varied from 17.04 ± 0.08 to 22.63 ± 0.12%, protein content from 45.46 ± 2.32% to 53.52 ± 1.23%, total fibre from 21.14 ± 0.11 to 22.67 ± 0.35% and lipid from 1.02 ± 0.02 to 1.55 ± 0.15%. The products were alkaline with pH ranging between 7.55 ± 0.01 and 8.38 ± 0.00 representing a titratable acidity varying from 0.08 ± 0.004 to 0.15 ± 0.01. Processing methods caused decreases of crude lipid (80%), total carbohydrates (60%) titratable acidity (45-84%) and an increase of fibres (30-40%), proteins (13-33%) and amino acids.

Keywords: Zamne; Technology; Nutritional composition

Introduction

Zamne is a traditional product from processing of *Senegalia macrostachya* syn. *Acacia macrostachya* seeds used as food in African countries including Burkina Faso (Figure 1). *Senegalia macrostachya* is a leguminous plant which belong to *Fabaceae-mimosoideae's* family [1,2]. Initially zamne was firstly a typical food of samo, mossi and gourounsi, three ethnical groups from Burkina Faso. Traditional processing of the seeds from *Senegalia macrostachya* usually involved successive cleaning and cooking (Figure 2), which can upgrade the nutritional values, sensory properties, and functional quality of the seeds.

Actually, zamne is largely consumed throughout the country particularly during festive ceremonies as a luxury food in families [2-5]. It is also sold as a street food [6]. Zamne production is based on traditional processes including successive boiling which is energy and time consuming process.

Differences in the traditional processes for zamne production occurred among ethnic tribes and these differences presumably influenced the quality of the final products.

The previous studies on zamne was focused on the physicochemical characterization of *Senegalia macrostachya* seeds and on its overall appreciation by the consumers [5,6]. Up to date very few works was done on the production processes and the nutritional quality of this food. This study aimed to describe in detail the technology of zamne

and to determine the biochemical characteristic of the product for its optimization. This is in view of an optimization of the processing parameters leading to a final product with improved nutritional and hygienic quality as well as improved stability.



Figure 1: *Senegalia macrostachya*. A: Tree; B: Opened pod; C: Uncooked seed; D: zamne: cooked seed.

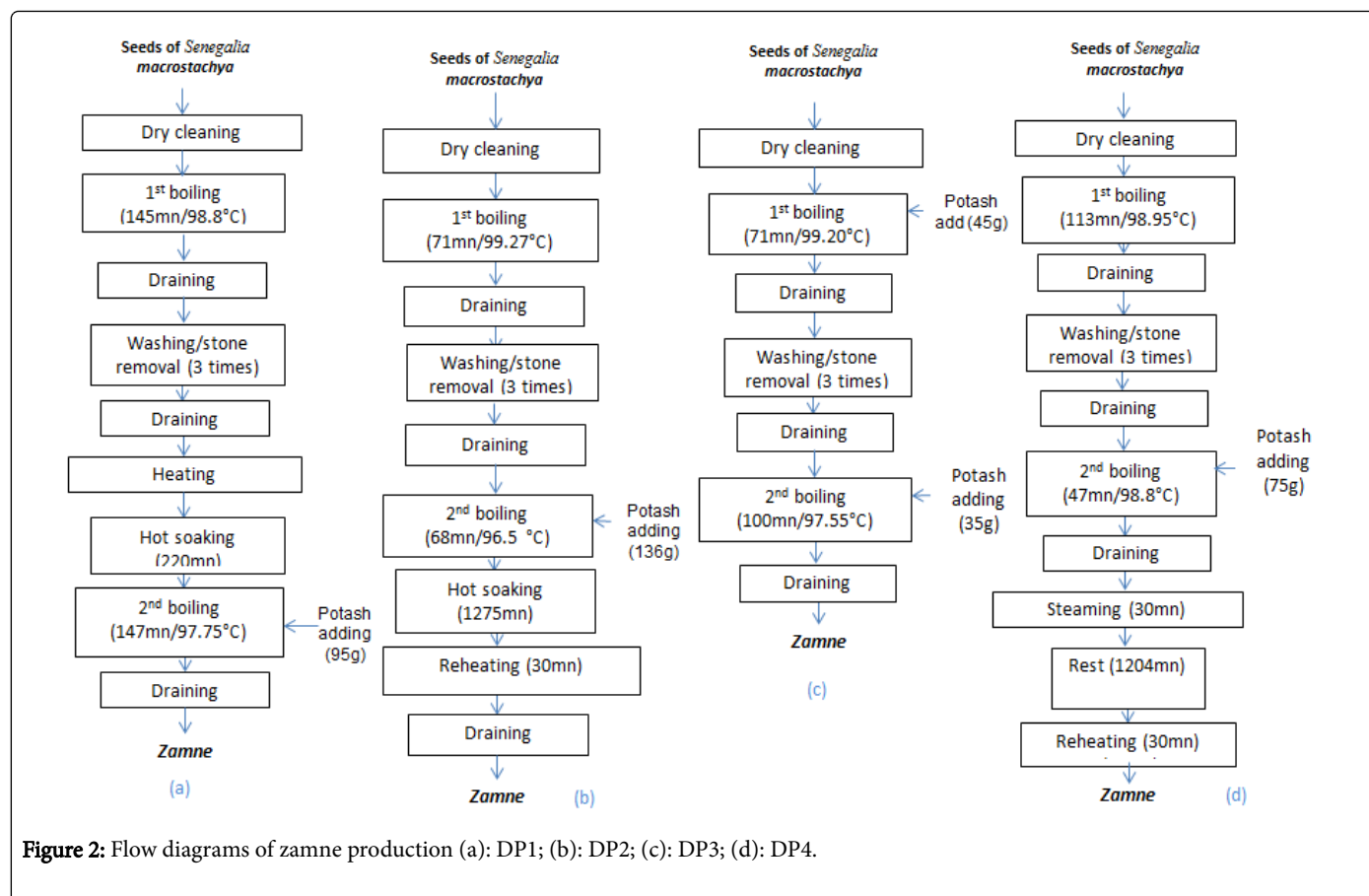


Figure 2: Flow diagrams of zamne production (a): DP1; (b): DP2; (c): DP3; (d): DP4.

Material and Methods

Three (03) production sites were identified in Ouagadougou, Burkina Faso and the production process followed three (03) times in each production site. The production steps and the processing condition were recorded. A flow diagram of each production site was established, and then a general diagram was proposed.

Experimental and controlled production was then reproduced in workshop-pilot with the aim to optimise the production parameters. Raw material samples (*Senegalia macrostachya* seeds) and ready to use zamne samples were collected during production and submitted to analysis.

Moisture, ash, and fat content were determined according to international standards methods [7-9]; carbohydrate and crude fibre was quantified according to Montreuil and Spik [10] and Deymie et al. [11] methods respectively. Protein content was determined using the differential method. Amino acids content was determined by PICO-TAG method using High Performance Liquid Chromatography (HPLC) [12].

The pH was determined according to the method described by Nout et al. [13]. All analysis was conducted in three replications and data were collected using Microsoft Excel 2013 while analysis of variance (ANOVA) by Tukey test and principal compound analysis (PCA) were performed for determination of statistical difference with a confidence interval of 95% using XLSTAT software, version 2015.4.01.22368.

Results and Discussion

Technology of production of zamne

The zamne processing steps varied according to producers' skills but the main steps remained (Figure 2). *Senegalia macrostachya* seeds are first dried and cleaned by winnowing and manual sorting. The cleaned seeds are cooked a first time and then washed and drained. During the washing step which is a water consuming operation unit, remaining impurities are eliminated. After washing, the product is cooked a second time with addition of ash leachate (softening agent). Cooked product are soaked and steamed.

The variation in zamne production technologies were tribute to the ethnical allegiance of producers, their knowledge level about the process and the raw materials properties. Sensory characteristics of the product seek by the customers is another factor of this variation. The variations are not only observed in the processes but also in the duration of each operation unit.

The duration of the first cooking varied from 71 min (DP2, DP3) to 145 min (DP1); the second one from 47 min (DP3) to 147 min (DP1). The duration of the hot soaking varied from 220 min to 1275 min. The duration of steaming was about 1234 min. According to producers, two or three of these heat treatments was assembled, explaining the variations observed on the total duration of the treatment. However, the diagram DP3 which have only the first and the second cooking, presents the shortest duration of treatment. The difference in the quantity of energy brought could influence the time of cooking [14]. In

this diagram, the ash leachate added in the first and the second cooking could help to reduce cooking time [14,15].

Table 1 showed the effect of processing on the physicochemical characteristics and the nutritional composition of zamne.

Samples codes	Moisture (g/100g)	Ash (g/100g DM)	Carbohydrates (g/100g DM)	Lipids (g/100g DM)	Proteins (g/100g DM)	Fibers (g/100g DM)	pH	Acidity d'H ₂ SO ₄ /100g DM (g)
AmPp	4.96 ± 0.10 ^d	4.72 ± 0.09 ^d	28.02 ± 0.05 ^a	10.99 ± 0.05 ^a	40.08 ± 0.49 ^a	16.19 ± 0.16 ^c	5.65 ± 0.01 ^e	0.47 ± 0.04 ^a
ZamDP1	81.27 ± 0.20 ^a	5.21 ± 0.14 ^c	19.61 ± 0.08 ^c	1.55 ± 0.15 ^b	51.32 ± 0.76 ^c	22.31 ± 1.27 ^{ab}	8.26 ± 0.01 ^b	0.08 ± 0.004 ^c
ZamDP2	80.69 ± 0.16 ^b	9.58 ± 0.13 ^a	22.63 ± 0.12 ^b	1.19 ± 0.18 ^{bc}	45.46 ± 2.32 ^b	21.14 ± 0.11 ^b	8.38 ± 0.00 ^a	0.15 ± 0.01 ^b
ZamDP3	79.92 ± 0.24 ^c	5.75 ± 0.03 ^b	17.04 ± 0.08 ^e	1.02 ± 0.02 ^c	53.52 ± 1.23 ^c	22.67 ± 0.35 ^a	8.20 ± 0.01 ^c	0.11 ± 0.00 ^{bc}
ZamDP4	79.54 ± 0.10 ^c	4.95 ± 0.06 ^d	18.90 ± 0.15 ^d	1.28 ± 0.07 ^{bc}	52.96 ± 0.68 ^c	21.91 ± 0.59 ^{ab}	7.55 ± 0.01 ^d	0.12 ± 0.00 ^{bc}
P value	<0.0001	<0.0001	<0.0001	<0.0001	0.001	<0.0001	<0.0001	<0.0001
t-test	1493.46	233.79	786.25	72.6	120.309	174.72	4034.18	42.18

Table 1: Physicochemical characteristics and nutritional value of *Senegalia macrostachya*'s seeds and zamne [Values with different superscript letters in a column are significantly different ($P \leq 0.05$); AmPp: *Senegalia macrostachya*'s seeds; ZamDP1, ZamDP2, ZamDP3, ZamDP4: zamne samples]

The moisture content varied from 79.54 ± 0.10% (DP4) to 81.27% (DP1) in zamne that of raw seeds was 4.96 ± 0.10%. There was not a significant difference between ZamDP3 and ZamDP4 regarding the moisture content. An increase was observed from raw material to final product, this increase can be explained by water absorption during the boiling [16].

Titrate acidity decreased during zamne processing. The decreases were 68.09%, 74.47%, 76.60% and 83% for ZamDP2, ZamDP4, ZamDP3 and ZamDP1 respectively. This decrease may be explained by the addition of ash leachate during the process, indeed the alkalizing agent added react with the free acids, reducing their content. There was no significant difference between ZamDP3 and ZamDP4 samples.

Ash content increased with the process varying from 4.72 ± 0.09% (raw seeds) to 9.58 ± 0.13% (zamne sample ZamDP2). A significant difference was observed in ash content between the raw seeds and the final product. The increase was probably related to the addition of the alkalizing agent (containing minerals) but also to the leaching of acidic component in the cooking water [14,17].

Indeed, Harper and Collin [18] reported that dried leachate of ash from sorghum is largely composed of potassium bicarbonate with smaller quantities of potassium chloride, silicate and sulphates, explaining then the increase of ash content in the final product.

The quantity of the softening agent (alkalinizing agent) added varied according to producers. However, ashes content of the ZamDP4 sample was not significantly different from that of the raw seeds that could be explained by lower quantity of ash leachate added in this sample (75g).

The fibres content increased with the zamne processing varying from 16.19 ± 0.16% to 22.67 ± 0.35% (zamne sample ZamDP3). There was a significant difference in the content of fibres between the raw seeds and zamne. Among the final products, the difference was significant only for samples ZamDP2 and ZamDP3. The increase of the fibres content during the process can be explained by the effect of cooking [19-21].

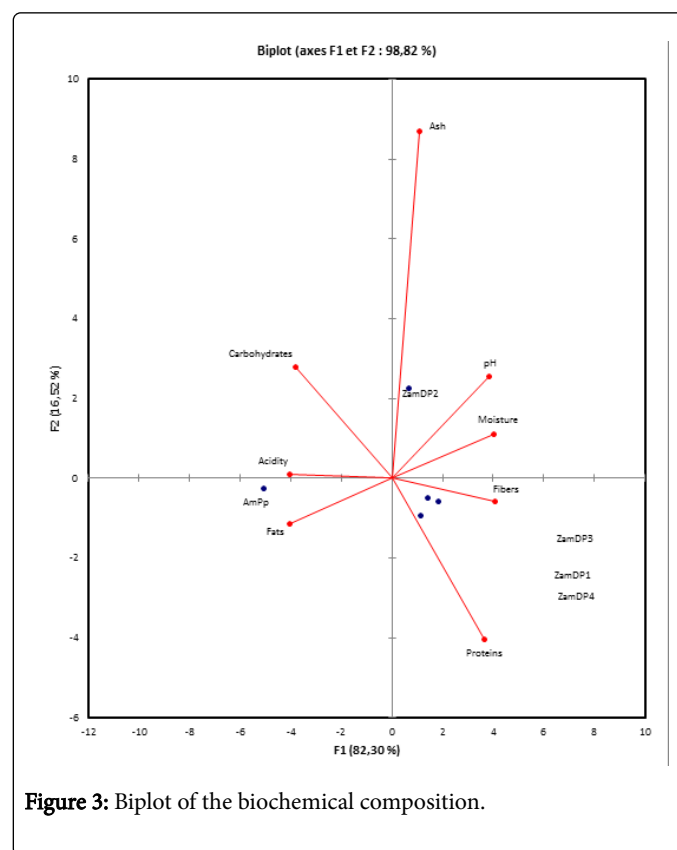


Figure 3: Biplot of the biochemical composition.

The carbohydrates content decreased with the process varying from 28.02 ± 0.05% (raw seeds) to 17.04 ± 0.05% (zamne sample ZamDP3). The reductions were about 19.24%, 30.01%, 32.55%, and 39.19% for ZamDP2, ZamDP1, ZamDP4 and ZamDP3 respectively. A significant difference was observed between the raw seeds and zamne. Wang et al. [19,20] observed the same effect during some leguminous (beans, chickpeas and lentils) cooking. The decrease in total carbohydrates content may be tribute to some various reactions of degradation and transformation of sugars during cooking in water, especially the

hydrolysis of the osidic links in alkaline medium [15]. Indeed, during the long cooking a certain amount of soluble carbohydrates was lost in the cooking water [22].

The lipids content decreased with the processing varying from $10.99 \pm 0.05\%$ (raw seeds) to 1.02 ± 0.02 (zamne sample ZamDP3). A significant difference was observed between the raw seeds and the final products. A reduction of more than 85% of fats was observed. The decrease might be mainly linked to two factors: the long cooking where a certain amount of lipid was lost in the boiling cooking water and by reactions between the fatty-acids and bases in alkaline medium which leads to the formation of soluble salt (sodic or potassic) [15,22].

The protein content increased with the zamne processing varying from $45.46 \pm 2.32\%$ to $53.52 \pm 1.23\%$ (zamne sample ZamDP3). A significant difference was noted between samples. An increase in protein content of 13 to 33% was observed. A similar observation was done during beans, chickpeas and lentils cooking [19,20].

The Figure 3 shows the analysis of sample's principal compound. The main axes F1 and F2 represent 98.82% of total inertia with respectively 82.30% and 16.52%. This analysis shows that ashes and

proteins parameters are well represented by the vertical axis F1. A regrouping of ZamDP1, ZamDP3 and ZamDP4 samples around proteins shows that the samples are rich in proteins. The sample ZamDP2 is close to the ashes parameter and traduces the richness of this sample in mineral compounds. A regrouping of the samples of zamne (ZamDP1, ZamDP2, ZamDP3 and ZamDP4) was observed around the parameters fibres, moisture and pH. Indeed, after cooking, the seeds of *Senegalia macrostachya*, an increase in moisture, fibres and an increase of pH due to the adding ash leachate were observed. The parameters acidity, carbohydrates, fats are well represented by the horizontal axis F2. The sample AmPp closed to these parameters traduces the richness of the raw seeds of *Senegalia macrostachya* in carbohydrates, fats and acidity.

The amino acids content varied with the zamne processing (Table 2). There was a significant difference between the raw material and the final products; and between the final products. These changes were variable according to the flow diagrams used. However a general decrease of the level of aromatic amino-acids (phenylalanine and tyrosine) was observed, due to a reduction in phenylalanine content.

Samples codes	AmPp	ZamDP1	ZamDP2	ZamDP3	ZamDP4	P value	t-test
Asp	$0.84 \pm 4, 10^{-4c}$	0.81 ± 10^{-4d}	$1.42 \pm 2, 10^{-4a}$	$1.36 \pm 3, 10^{-3b}$	0.57 ± 10^{-2e}	<0.0001	958.22
Glu	0.96 ± 10^{-3e}	$1.22 \pm 5, 10^{-4c}$	1.58 ± 10^{-3b}	$1.77 \pm 4, 10^{-3a}$	$1.02 \pm 3, 10^{-3d}$	<0.0001	2511.33
Ser	0.32 ± 10^{-4e}	0.41 ± 10^{-4d}	$0.66 \pm 2, 10^{-4a}$	0.60 ± 10^{-3b}	0.49 ± 10^{-3c}	<0.0001	3457.47
Gly	$0.35 \pm 5, 10^{-3c}$	0.34 ± 10^{-4d}	$0.52 \pm 2, 10^{-4a}$	$0.52 \pm 4, 10^{-4a}$	$0.38 \pm 4, 10^{-4b}$	<0.0001	839.03
His	0.00 ± 0.00^c	0.00 ± 0.00^c	0.26 ± 10^{-4a}	0.14 ± 10^{-3b}	0.00 ± 0.00^c	<0.0001	797.12
Arg	0.45 ± 10^{-4d}	0.60 ± 10^{-4c}	$0.74 \pm 3, 10^{-4b}$	0.88 ± 10^{-3a}	$0.60 \pm 5, 10^{-4c}$	<0.0001	5609.72
Thr	$0.18 \pm 2, 10^{-3b}$	0.00 ± 0.00^c	0.00 ± 0.00^c	$0.32 \pm 3, 10^{-3a}$	0.00 ± 0.00^c	<0.0001	278.74
Ala	0.26 ± 10^{-3d}	0.25 ± 10^{-4e}	0.34 ± 10^{-4b}	0.40 ± 10^{-4a}	$0.27 \pm 3, 10^{-4c}$	<0.0001	2874.04
Pro	$0.51 \pm 2, 10^{-4e}$	$0.54 \pm 4, 10^{-5d}$	0.70 ± 10^{-4b}	0.88 ± 10^{-3a}	0.55 ± 10^{-3c}	<0.0001	4441.92
Tyr	0.29 ± 10^{-4e}	0.37 ± 10^{-4d}	0.50 ± 10^{-4b}	$0.55 \pm 4, 10^{-4a}$	$0.38 \pm 4, 10^{-4c}$	<0.0001	7067.35
Val	$0.26 \pm 4, 10^{-5d}$	0.36 ± 10^{-4c}	$0.25 \pm 3, 10^{-3e}$	0.55 ± 10^{-3a}	$0.42 \pm 4, 10^{-4b}$	<0.0001	1155.28
Met	0.00 ± 0.00^c	0.00 ± 0.00^c	$0.31 \pm 3, 10^{-3a}$	0.12 ± 10^{-3b}	0.00 ± 0.00^c	<0.0001	273.22
Cys	0.00 ± 0.00^a	0.00 ± 0.00^a	0.00 ± 0.00^a	0.00 ± 0.00^a	0.00 ± 0.00^a		
Ile	$0.26 \pm 3, 10^{-5d}$	$0.38 \pm 4, 10^{-4c}$	$0.69 \pm 3, 10^{-4a}$	0.11 ± 10^{-4b}	$0.51 \pm 2, 10^{-4e}$	<0.0001	10333.13
Leu	$0.26 \pm 3, 10^{-5d}$	$0.38 \pm 4, 10^{-4c}$	$0.69 \pm 3, 10^{-4a}$	0.11 ± 10^{-4b}	$0.51 \pm 2, 10^{-4e}$	<0.0001	10333.13
Phe	$2.58 \pm 3, 10^{-4a}$	$0.29 \pm 2, 10^{-4d}$	$1.07 \pm 4, 10^{-4b}$	$0.51 \pm 3, 10^{-3c}$	$0.53 \pm 5, 10^{-4c}$	<0.0001	75.86
Lys	0.28 ± 10^{-5e}	0.49 ± 10^{-3d}	$0.94 \pm 4, 10^{-4a}$	$0.79 \pm 2, 10^{-3b}$	0.74 ± 10^{-3c}	<0.0001	2612.62

Table 2: Amino-acids profile of zamne and the *Senegalia macrostachya* seeds (in g/100g of DM) [Values with different superscript letters on a line are significantly different ($P \leq 0.05$); AmPp: *Senegalia macrostachya*'s seeds; ZamDP1, ZamDP2, ZamDP3, ZamDP4: zamne samples]

An increase in the level of amino-acids with ramified chain was observed; the content in valine was higher in zamne compared to raw seeds excepted in sample ZamDP2. The contents in leucine and isoleucine remained equal in various samples despite the variation in the process. According to Pana [23], that could be beneficial for the health of consumers, particularly on the insulinic issue.

It was noted that the sulphur amino-acids which were absent in the raw material, are found in the final products. The presence of methionine was observed in the final products of diagrams DP2 (ZamDP2) and DP3 (ZamDP3).

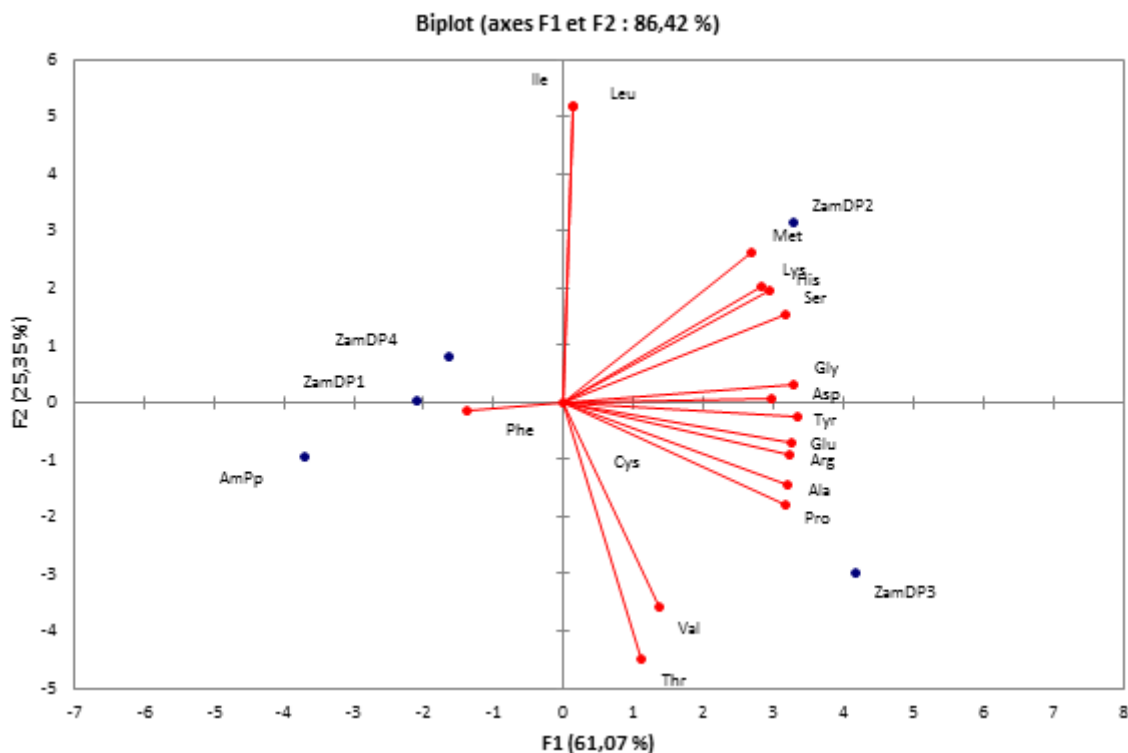


Figure 4: Biplot of the amino acid profile.

Glutamic acid becomes the major amino-acid in the final products with a content ranged between $1.02 \pm 3, 10^{-3}$ (ZamDP4) and $1.77 \pm 4, 10^{-3}$ g/100g DM (ZamDP3).

The Figure 4 biplot represents the analysis of principal compound of the amino acids profile. The main axes F1 and F2 respectively present 61.07% and 25.35% of total inertia so 86.42% in total. The parameters isoleucine, leucine, threonine and valine are well represented by the horizontal axis F1, and the other parameters by the vertical axis F2. Samples ZamDP2 and ZamDP3 present a homogeneous distribution compared to the various amino acids whereas the samples ZamDP1 and ZamDP4 are gathered with the AmPp sample. Indeed, ZamDP1 and ZamDP4 present low contents of amino acids whereas the samples ZamDP2 and ZamDP3 have a varied composition and high contents of amino acids.

Conclusion

The production of zamne is based on culinary practices with different variations. These variations are observed in the steps, their sequence and their duration. Whatever the producers, the flow diagram presented the operations of cleaning, double cooking and washing/drainage. Ash lye solution was added as softening agent. The various modifications were applied according to the consumer's appreciation. However, these various processes had a variable impact on the nutritional quality of zamne. The contents of fibres, ashes and proteins increased while those of the fats and sugars decreased. An improvement of the profile of the amino-acids was observed.

Comparing the different diagrams the DP2 one could be used for the production of zamne with higher content in mineral and carbohydrates; Diagram DP3 for higher content in fibres and proteins.

Conflict of Interest

All authors have no conflicts of interest to declare.

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