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EFFECT OF LEMON AND TAMARIND ON THE COOKING TIME, PHYSICO-CHEMICAL AND FUNCTIONAL CHANGES DURING PRODUCTION OF PRECOOKED MACABO (XANTHOSOMA SAGITTIFOLIUM) FLOURS

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KEYWORDS: Kouakoukou; chemical profile; textural properties.

ABSTRACT
This study was carried out to produce Macabo flour as an ingredient for the preparation of a common food paste locally called Kouakoukou. The tubers were precooked using four different techniques [whole steamed tubers (WST), steamed slices (SS), whole boiled tubers in tamarind (WBTT) and lemon (WBTL)] followed by air drying and milling through a 500µm sieve mesh. Flours so produced were evaluated for their moisture, proteins, carbohydrates, crude fat, ash, some minerals, oxalate, soluble proteins, and soluble sugars content. The textural properties (breakdown, hardness, adhesiveness, cohesiveness and gumminess) of the different pastes so produced were analysed using a Lloyd instrument set to produce double compression load of 50N. Results revealed that the chemical characteristics of the flours varied with the cooking method.

INTRODUCTION
The Macabo (*Xanthosoma sagittifolium*) contains a low percentage of proteins (4-8%) but a high amount in carbohydrates (63-90%), which provide the main source of calories in the diet of the people around the world. The human consumption of the Macabo is carried out mainly cooked or precooked flour (Nip, 1997). Heat treatment of Macabo during cooking imparts certain variations in the flavour, the texture and in all those characteristics that can influence significantly in the attributes of quality of the food (Agblor and Scanlon, 1998). In Macabo, the abundance of starch in the cells and the size of starch grains have been reported as being important for the final texture (Barrios, Newsom, and Miller, 1963; Ridley and Hogan, 1976), as have the structure of the cell wall polymers (Parker, Newsom, and Miller, 1995; Marle van, et *al.*, 1997). During heating the starch granules within the cell absorb the cellular water and swell in the form of a gel. Other major changes that occur are the loss of integrity of the cell membranes, resulting in a loss of turgor and the free diffusion of cellular contents throughout the tissue. Besides, there is the effect of heat on the structure of the cell wall and the denaturation of protein, leading to a reduction in cell cohesion (Thygesen, Thybo, and Engelsen, 2001). The net result of these changes is gelled starch and a softer tissue in which the cells are more easily separated. One of the traditional applications of the Macabo is the preparation of the «Kouakoukou», in which cooking time and texture are the most outstanding factors to achieve the acceptability by the consumer.

The process includes cooking, peeling and pounding. This is very hard for city dweller to process. During the cooking the starch goes through a gelatinization and retrogradation, the amylase chains intersect ending up being insoluble and make the cells of the Macabo firm which remains unalterable during the drying (Agblor and Scanlon, 1998). Texture and colour are the most important parameters in the definition of the quality of potato products, but usually their subjective measurements do not give any reproducible results due to the complicating factors related to human perception (Thybo and Martens, 1999; Martens and Thybo, 2000). In order to understand the factors that can affect the texture and the colour of the Macabo products during processing, instrumental techniques have been developed for quantifying those parameters (Thybo and Martens, 1999; Martens and Thybo, 2000; Thybo, Bechmann, Martens, and Engelsen, 2000; Thybo, 2001). One can see the importance that has the precooking and the necessity of having a tool that allows prediction of the texture of the Macabo strips in function of their dimensions, forms, and precooking conditions. The objectives of this work were: (1) to determine the

optimal time which induce less physicochemical changes during cooking, the kinetic parameters of the variation of the flour during the cooking and to develop a model that allows the cooked Macabo's tuber.

MATERIALS AND METHODS

Raw material

The red variety of *Xanthosoma sagittifolium* tuber, locally called «Ibo coco» used in this study were freshly harvested from a farm in Bini town (Ngaoundere-Cameroon). Tubers were washed in clean water.

Cooking operation of tubers

Cooking operation was carried out in the pressure cooker.
The clean tubers were divided into 4 groups. The tree first groups were cooked for 0, 5, 10, 15 and 20 min in tree types of solution. Firstly process were performed in 1500 mL of water, secondly in 1500mL of the lemon (*Citrus sp*) solution and thirdly in 1500 mL of tamarind (*Tamarindus indica*) solution. The last group were sliced before had been cooked by steam.

Flours preparation

All cooked tubers were peeled, sliced and dried in the solar dryer. The dried slices were first hammer milled (Culatti polymix) equipped with 500µm screen. The flours were packed and stored for further analysis.

Chemical analysis

Moisture content was determined by drying samples in an air-oven at 105°C to constant weight. Total protein (Nx6.25) was analysed using approved methods of Kjeidahl (AACC 46-11A) (AACC.1990). Protein content was evaluated by titration using sulphuric acid 0.2 $mol.l^{-1}$ in semi automatic machine *GEHARDT* (Paris.France).Reduced sugars were evaluated using the DNS colorimetric method of Fisher and Stein (1961). Fat, ahs and minerals contents were determined using methods of American Association of cereal chemists (1990).

Functional properties

Water absorption capacity (WAC) and water solubility Index (WSI)

WAC was determined essentially by the method of Phillips et *al.*, (1988), while WSI was determined by the method of Anderson et *al.*,1969. A weight of 0.5g (M_0) of flour was mixed in 10 mL of distilled water and mechanically agitated for 15 min in a KS 10 agitator. The mixture was centrifuged at 5000rpm for 15 min on a desktop centrifuge (Bioblock scientific MLWT. 62.1). The resulting sediment (M_2) was weighed and then dried at 105°C for 24h and the dry weight (M_1) determined. The water absorption capacity (WAC) was then calculated.

Soluble protein content

The soluble protein content of the extract was determined using the Bradford assay described by Bollag and Edelstein (1991). The method involves the addition of acidic dye to the protein solution, and subsequent measurement of absorbance at 595nm with a spectro-photometer. Extract samples were first diluted 2:1 (v/v), extract:water). A standard curve was prepared using casein in concentrations ranging from 0.25 to 1.5 mg/mL. to 100µl of each standard or extract sample solution, 5.0 mL of dye solution was added in a test tube. The tube was vortexed and held at room temperature (24°C) for 30 min. before absorbance was measured.

Absorbance values at 280 and 420 nm

The extract was diluted 1:25 (v/v, extract: water) for measurement of absorbance at 280 and 420 nm, respectively.

Calculation of cooking indices

Cooking indices were calculated by normalizing indicator values with respect to uncooked flour.

$$\text{Cooking index} = \frac{\text{Value of indicator for cooked flour}}{\text{Value of indicator for uncooked flour}} \quad (1)$$

Determination of blue value index

The blue value index was determined by a method adapted from Mullins *et al.* (1955) and Escher *et al*. (1979). 0.5 g of Macabo flour were heated in 10 mL distilled water at temperature between 30°C to 90°C for 15 min. 1

min after extraction, the suspension was mechanically agitated for 15 min in a KS 10 agitator. The mixture was centrifuged at 5000rpm for 15 min on a desktop centrifuge (Bioblock scientific MLWT. 62.1). The absorbance at 660nm of the sample against a blind value (1 mL 0.01 mol/l iodine solution and 2 mL distilled water) was determined in 1 cm cuvettes with Spectronic Genesys 2 PC (Spectronic instruments, USA) and is termed A650. Measurements were done at least as a duplicate. The blue value index was calculated on the basis of a net weight of 1 g initial dry sample as shown in Eq. (2), where w is the sample weight [g] and dm the sample dry matter [g/100g].

Blue value index = (A650/w) x (100/dm) (2)

Vortex induced cells separation (VICS)

Vortex induced cells separation was analyzed by modified method of Parker and Waldron (1995). A part of cooked sample was removed after each cooking time. A weight of 1g of sample was mixed in 10 mL of distilled. The tube was vortexed at room temperature (24°C) for 25 min. The VICS was determined as the rate of cell separation the basis of a net weight of 1 g initial dry sample.

Resistant starch (RS)

Resistant starch content were analyzed essentially as described by Goni et *al.*(1996). Samples were mixed with water and protease was added before heating in the boiling water bath. Then, the amount of RS was determined by digestion with amyloglucosidase after solubilization in 2 M KOH.

Oxalate content

The oxalate content was determined using the method originally employed by Ukpabi *et al*., 1989. The procedure involves three steps: digestion, oxalate precipitation and permanganate titration.

Digestion

At this step, 2 g of flour was suspended in 190 mL of distilled water contained in a 250 mL volumetric flask; 10 mL of 6M HCL was added and the suspension digested at 100°C for 1h, followed by cooling, and then made up to 250 mL before filtration.

Oxalate precipitation

Duplicate portions of 125 mL of the filtrate were measured into beaker and four drops of methyl red indicator added, followed by the addition of concentrated NH_4OH solution (dropwise) until the test solution changed from its salmon pink colour to a faint yellow colour (pH 4-4.5). Each portion was then heated to 90°C, cooled, and filtered to remove precipitate containing ferrous ion. The filtrate was again heated to 90°C and 10 mL of 5 % $CaCl_2$ solution was added while being stirred constantly. After heating, it was cooled and left over the night at 5°C. The solution was then centrifuged at a speed of 2500 rev/min for 5 min. The supernatant was decanted and the precipitate completely dissolved in 10 mL of 20% (v/v) H_2SO_4 solution.

Permanganate titration

At this point, the total filtrate resulting from digestion of 2 g of flour was made up to 300 mL. Aliquots of 125 mL of the filtrate were heated until near-boiling, and then titrated against 0.05M standardized $KMnO_4$ solution to a faint pink colour which persisted for 30 s. the calcium oxalate content was calculated using the formula:

$((Tx (Vme) (DF)x 10^5) /(V_TA(ME)x m_f))(mg/100g)$

Where T is the titre of $KMnO_4$ (mL), Vme is the volume-mass equivalent (i.e. that 1 cm^3 of 0.05 M standardized $KMnO_4$ solution is equivalent to 0.00225 g anhydrous oxalic acid), DF is the dilution factor V_TA (2.4, where VT is the total volume of filtrate (300 mL) and A is the aliquot used (125 mL)), ME is the molar equivalent of $KMnO_4$ in oxalate ($KMnO_4$ redox rxn. (5)) and m_f is the mass of flour used.

Panelists/sensory attributes

The sensory properties of the precooked flour were investigated with the use of a sensory panel according to the principles of qualitative descriptive R.A (Stone *et al*., 1985). Panelists were selected from a group of 15 young and healthy candidates. The panelists were congratulated for their participation and testing took place at the

sensory facilities of Nutrition and Food Research Science of ENSAI, Ngaoundere. Attributes were ordered according to the chronological order in which they are perceived (1= no liked ; 5= fair liked; 7= like 9=like very much).

Procedure

Panelists were seated in sensory booths with appropriate ventilation and lighting. The panelists produced sensory profiles for each of the test flours, presented once in random order during a 2.5 h session at a rate of one food every 5 min. Over three sessions, each food was presented in three replicates. Each flour was taken into the mouth and taste/flavour and mouth feel attributes were rated in the order in which they were perceived.

Statistical analysis

The data reported are averages of triplicate observations. The data were subjected to statistical analysis using *Stat Graphics 3.0* (Manugistics, Rockville, Maryland, U.S.A.) statistical package.

A principle component analysis (PCA) of measured tubers properties was carried out to provide a ready means of visualizing the differences and similarities among the five Macabo treatments in terms of these properties.

RESULTS AND DISCUSSION

Chemical analysis

The proximate composition of the cooked Macabo flours analysed is presented in table 1. The results showed that the proteins, ash, soluble oxalate, fats, soluble sugar and minerals contents varies in cooked Macabo flours. The difference among the means of different contents found to be significant at the $p<0.01$ level. The decrease in the observed value is due to the combine effects of the leaching and the heat. Those value are in agreement with the results found by Nip *et al*., 1997.The level of soluble sugars is high in WBT but this level is very less in SS. This result showed that leaching is very reduced in WBT but high in SS. This result is in agreement with the result found by Njintang *et al*. (2002) on the physicochemical changes during the drying and cooking Macabo.

The decreases in the level of soluble oxalate were observed in the cooked flours. The higher value is observed in WBTL (1.4 mg) and the lower one is observed in SS (0.86 mg).

Proteins are very less the value where between 2.08 and 2.57.

Functional properties

Determination of blue value index

The variation of the index of gelatinisation of the starch (Blue Value index, BVI) Macabo during cooking is given in figure 1. In general the Blue Value index of the Macabo increases according to exponential kinetics during cooking, attesting that gelatinisation of the starch takes place. For the WBT, the increase is fast and stabilize toward 300 eq.DO/100g, value near of the steam slice (SS) one. But then cooking in the acidic solutions (tamarind and lemon) drags a weak increase of BVI suggesting a gelatinisation limited of the starch in acidic solution, either a hydrolysis of the starch. The starchy product gelatinisation is a very important phenomenon because it depends on the quality of the final product that drifts. Depending to the results gotten we can say that the SS and WBT will give products that come closer but different of the two other treatments (WBTT,WBTL) which are cooked in tamarind and lemon solutions.

Reducing sugar

In addition of the gelatinisation of the starch, the starchy product cooking often drags a hydrolysis of the starch. Figure 2 present the variation of the reducing sugar rate. This figure shows that the rate of sugars varies in most treatments, exception is observed by the SS where the rate increases continually. This result suggests that, the observed marked increase caused during cooking may be due to the thermal degradation. They are similar to results from aqueous boiling of cocoyams by Osisiogu *et al* (1974). The increase of the reducing sugar rate could influence the sweetness of the dough and the storage of flours that result.

Resistant starch

The two phenomena gelatinisation and hydrolysis of the starch generally influence his digestibility, and therefore his availability. During cooking a determination of the resistant starch has been done and results are presented in

the figure3. In general, the resistant starch rate lowers with the some cooking time either the treatment of cooking applied. The decrease is less important for the cooking of slices (SS) and the cooking of tubers in the water of faucet (WBT).This result is not in agreement with the literature. The formation of resistant starch is temperature dependant, its high temperature depleting the high level of resistant starch (Eerlingen *et al*., 1993).

Another modification no less important during the cooking of the Macabo is bound to proteins. Figure 4 watch of the time and fashion of cooking on the soluble proteins of the Macabo. In general the soluble protein rate decreases during cooking. This reduction is weak for the cooking of slices but important for the other treatments. The denaturation by structural modification of proteins would be bound to this reduction of the solubility that is accentuated when the tuber is dived in a solution. Although the content in proteins of Macabo is weak, it is possible that the soluble proteins can play a role in the texture of the dough and by there to influence his acceptability. Whatever, the WBT is the type of cooking used by populations for the preparation of the dough, and only high level in soluble proteins can be damaging to the quality of the dough gotten.

If phenomena of gelatinisation and hydrolysis are important in most the starchy products, the irritation is even more important for what is the Macabo. Indeed the Macabo is irritating when it is not cooked well. The irritation constitutes then a determining important to value the time of cooking of the Macabo. The evaluation of the irritation during cooking showed that beyond of 10 min the irritation is eliminated some either the treatment. This short enough time would be bound to the fact that the variety Ibo darling would contain less oxalate, the incriminated irritating factor (Njintang *et al*., 2003). An assessment of the rate of calcium oxalate during cooking shows a meaningful reduction of the oxalate rate for cooking in water and in the acidic solutions. The cooking of steamed slices would not drag meaningful modification of oxalates. This result suggests that boiling affected the highest reduction in oxalate. The reduction during boiling must be due to leaching, because some oxalate fractions are water-soluble (Osisiogu *et al*., 1974; Irvine, 1969; Bradbury and Holloway, 1988, Njintang *et al.*, 2003)
All indices generally decrease with increasing cooking time. Absorance at 280 nm is generally proportional to protein concentration (Bollag *et al*., 1991). It was thought that the A420 index would provide a measure of Maillard browning, thus was expected to increase with increased cooking time.

Texture parameters

Harness

Variation of the texture: texture parameters that are hardness, adhesiveness, cohesiveness and the gumminess have been evaluated during cooking. The Figure 8 shows the variation of the tuber hardness during cooking. As waited, the hardness of the tubers decreases during cooking. This reduction is more important for WBT. The hydrolysis and the leaching of the starch that take place for cooking in the acidic solutions would have dragged a hardening of tubers. We observed that beyond 12 min of whole boiled tubers (WBT), some tubers fissured prominent that the tuber is cooked. It was not the same for cooking in the acidic solutions where have been made after 15 min of cooking on the similar observations.

Adhesiveness

In the same way, adhesiveness (the faculty of a product to adhere to a surface) tubers increase during cooking (figure 9). This increase would be bound both to the increase of water contents and the secretion of mucilage, present in the Macabo. The increase is important when the tuber is immersed in the water of faucet but weak for tubers immersed in the acidic solutions. It agrees to mention that miscellaneous plays an important role in the texture of the dough while giving its behaviour viscoelastic (Nip, 1997; Njintang *et al*., 2003). The hydrolysis of miscellaneous by acid would be responsible of this weak increase.

Cohesiveness

The cohesiveness of tubers, witch indicated the internal strengths that maintain the intact tuber are represented on the figure 10. In all treatments, the cohesiveness decreases. This results are compliant to waiting in the fact that the cooking of the Macabo tuber as for starchy products, translates himself always by a separation of cells (Njintang, 2003). The decrease of the cohesiveness interns in the case of cooking in tamarind is more important, all at less during the first minutes of cooking. In the 25 minutes of cooking values of the cohesion intern for every treatment offer to come closer. It is obvious of as much more that the finality of cooking is the complete separation

of cells. In this title we can think that the cooking of the tuber is finished in the 25 min. of cooking. For whole boiled tuber and tamarind, cooking seems optimal in the 12 min. of cooking.

Guminess

The guminess of the tuber shows a similar variation to cohesiveness (Figure 11). We can also report the similarity of the guminess for all treatments toward the 25 min of cooking. This result could be explained as effect of hydrolysis of starch granule by acidic solution. This effect affects gel formation and decreases guminess. The same observation was made by Ramesh *et al*. (2004), on Macabo.

sensory attributes

The sensory attributes of tubers and flours were recorded during cooking. Results were recorded as Principal component analysis (PCA).

The PCA plots provide an overview of the similarities and differences between treatments of the different tubers, and of the interrelationships between the measured properties. The first and the second principal components (PC1 and PC2) explained 52% and 32%, respectively, of the overall variation. The distance between the locations of any cooking times on the score plot is directly proportional to the degree of difference/similarity between treatments (Fig. 10). The irritation is located at the far left of the score plot with a large negative score in PC1, while the bitter taste had a large positive score (Fig.11). However, they differ only slightly in terms of PC2. Overall, these tubers exhibited the greatest differences in their properties during cooking. The manual cooking hardness test is directly proportional to irritation in all treatment. When the first is decreasing, the second is decreasing to. This minds that, when tubers are soft, the irritation is reduced completely. In other hand, the increase of cooking is much closed to the increase of acid and bitter taste. This result minds that when the tubers are soft, water is diffusing in the heart of the crops and this were lead to the change of the tubers taste. The spatial distribution of cooking times is represented in figure 13. The results collected shows tri clusters. The first one is regrouping all flours which were contaminated by lemon or tamarind taste. The second group is characterised by the higher irritation and the third group by the higher cooking time. Those results are similar to the result of Njintang *et al*. (2002) on the Major constraints associated with the use of Macabo (*Xanthosoma sagittifolium)* flour as raw material for the preparation of *Kouakoukou.* Those authors incriminated the effect of heat on the gelatinisation of starch. This induced the softening of the tuber.

CONCLUSION

In this experiment, chemicals characteristics varied with the cooking methods. all process induced reduction of nutriments level. Functional properties are highly correlated to cooking time. Textural parameters are proportional to cooking time. The principle component analysis of sensory analysis showed that cooking methods were lead to tri clusters depending to irritation degree, lemon and tamarind flavour and softening.

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Table 1: chemical composition of different Macabo flours

Samples	Proteins (mg/100g d.b)	Ash (mg/100g d.b)	Soluble sugars (mg/100g d.b)	Soluble Proteins (mg/100g d.b)	Soluble Oxalates (mg/100g d.b)	Fats (mg/100g d.b)
TT	2.531±0.1 ^{d}	5.03±0.1 ^{d}	17.83±0.1^{c}	4.10±0.6^{d}	1.28±0.03^{e}	1.58 ±0.2^{c}
WBTT	2.49±0.08 ^{c}	4.57±0.09 ^{c}	8.93±0.13^{b}	1.95±0.2^{a}	1.05±0.01^{b}	0.26 ±0.04^{ab}
WBTL	2.11±0.07^{b}	1.55±0.3 ^{b}	12.61±0.4^{d}	1.92±0.3^{a}	1.4±0.023^{d}	0.413 ±0.05^{b}
SS	2.08±0.01^{a}	1.2±0.05 ^{a}	7.76±0.3^{a}	2.71±0.1^{b}	0.86±0.01^{a}	0.263±0.012^{ab}
WBT	2.57±0.16^{de}	6.2±0.1 ^{e}	13.84±1.5^{e}	3.60±0.2^{c}	1.1±0.01^{c}	0.178±0.03^{a}

Table 2: Some minerals composition of different Macabo flours

Samples	Ca (mg/100)	Mg (mg/100g)	Na (mg/100g)	Al (mg/100g)	Fe (mg/100g)	Mn (mg/100g)	Zn (mg/100)	Cu (mg/100g)
WBTT	6.76±0.4^{acd}	59.69±0.1^{c}	27.03±0.09^{d}	1.2±0.02^{d}	2.76±0.04^{cd}	4.16±0.03	24.87±1.1^{c}	1.2±0.02^{c}
WBTL	5.5±0.3^{a}	60.36±0.2^{d}	23.08±0.1^{b}	0.9±0.04^{b}	2.3±0.06^{b}	0.95±0.1^{b}	20.95±2.1^{b}	1.17±0.04^{b}
SS	5.75±0.2^{ab}	55.4±0.1^{b}	16.15±0.2^{a}	0.7±0.02^{a}	1.9±008^{a}	0.76±0.01^{a}	16.15±1.2^{a}	1.13±0.05^{a}
WBT	6.6±0.5^{c}	51.7±0.1a	25.33±0.1^{c}	1.05±0.03^{c}	2.7±0.01^{c}	4.09±0.02^{c}	22.9±0.1^{b}	1.19±0.03^{b}

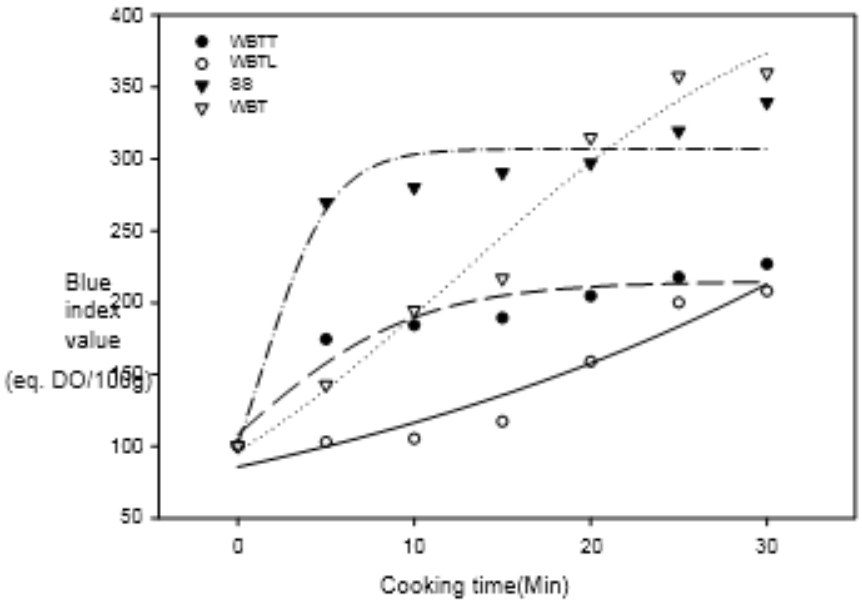
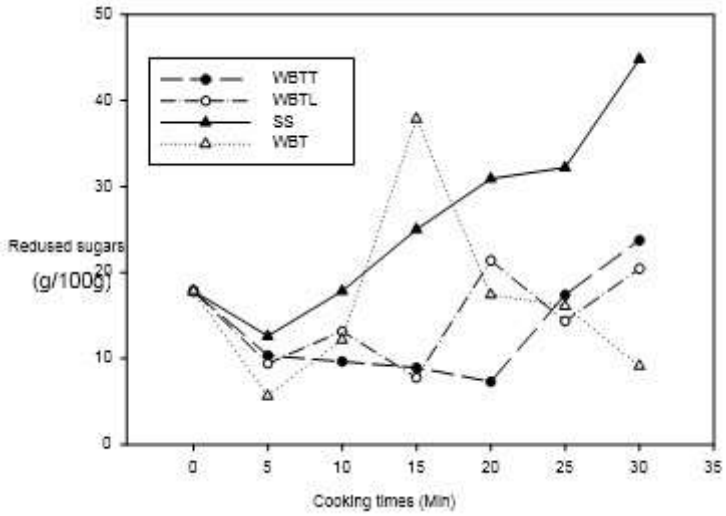
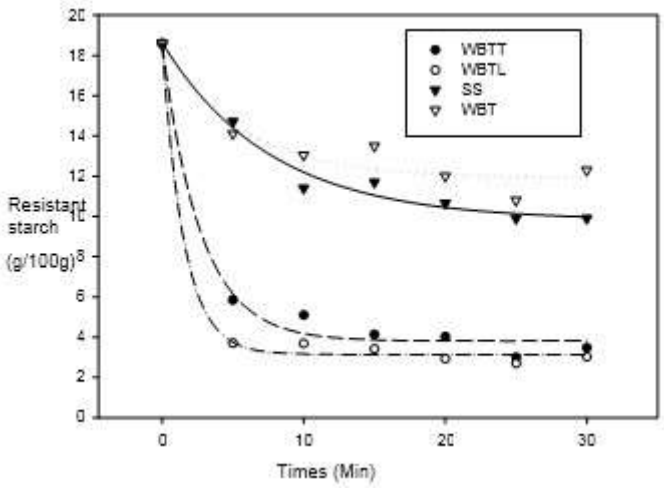


Figure 1: Blue index value during cooking



Face 2: Soluble sugars of Macabo during the cooking.



Face 3: Variation of the resistant starch rate during cooking of Macabo

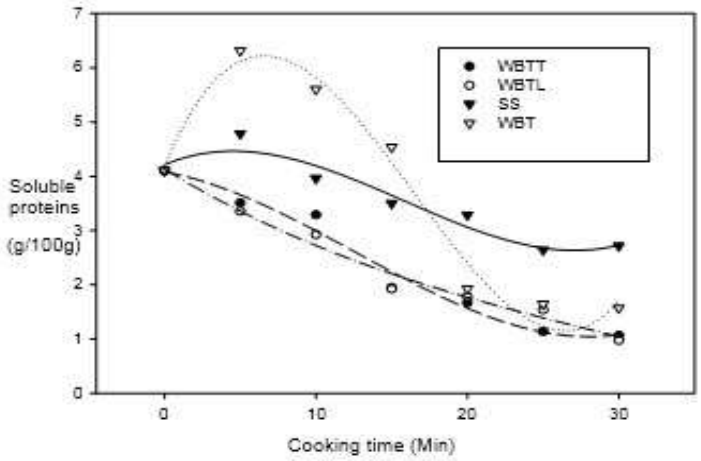


Figure 4 : Variation of solubles protein during cooking of Macabo

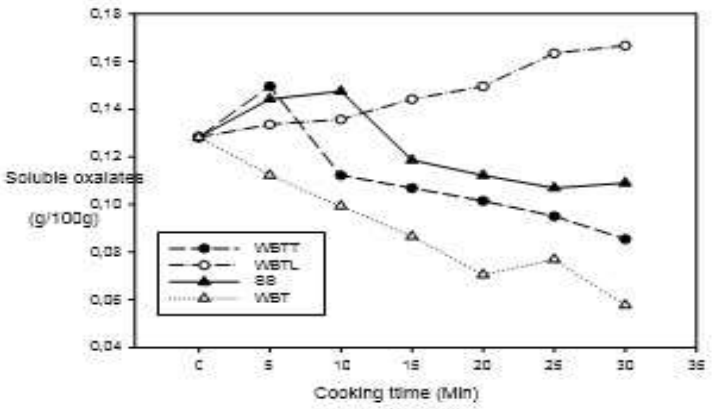


Figure 5 : variation of soluble oxalates during cooking time

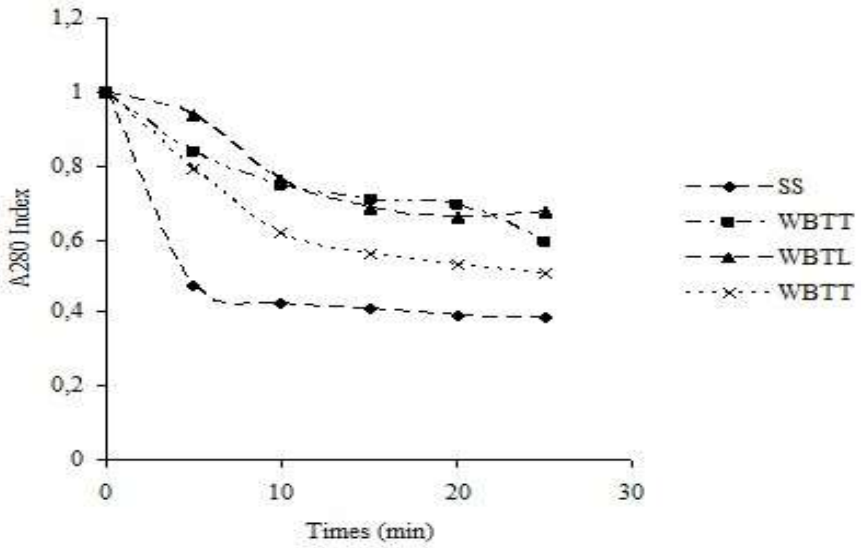


Figure 6: Experimental (points) and model (lines)values of A280 Index

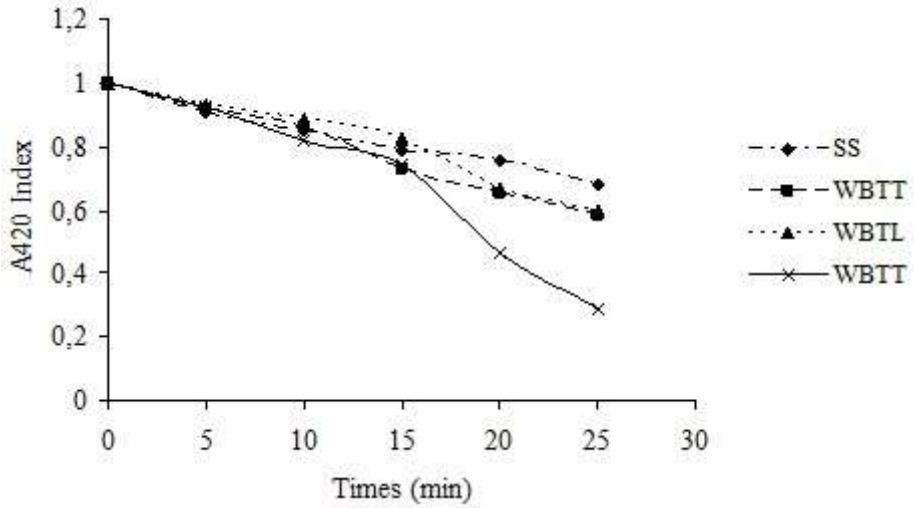


Figure 7: Experimental (points) and model (lines)values of A420 Ind

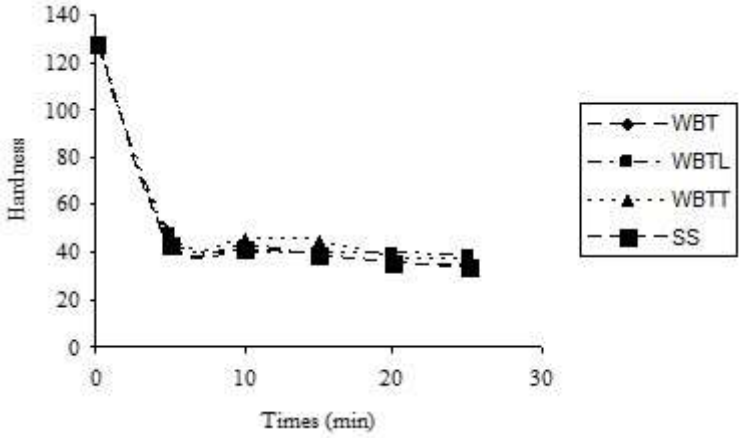


Figure 8: variation of the tuber hardness during cooking

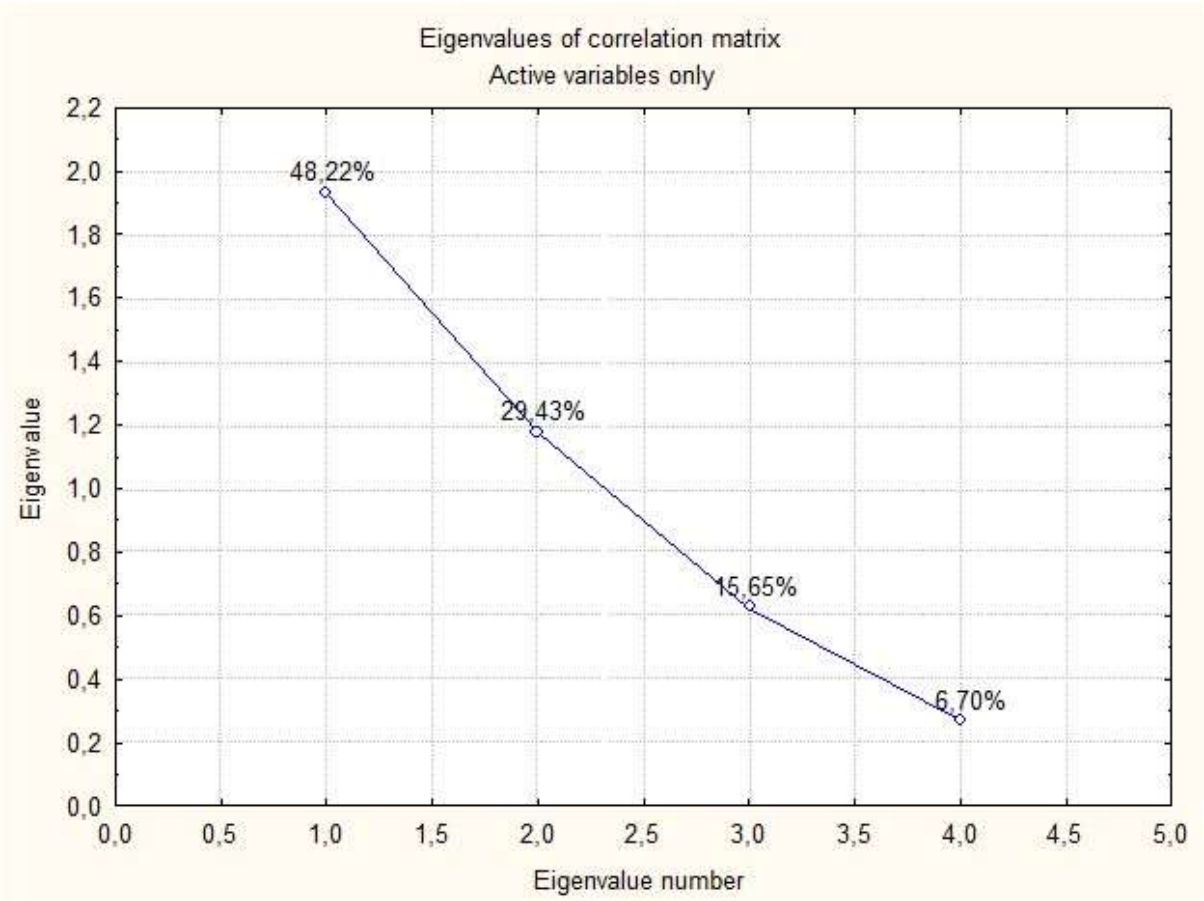


Figure 9 : real values of CPA associated to cooking times

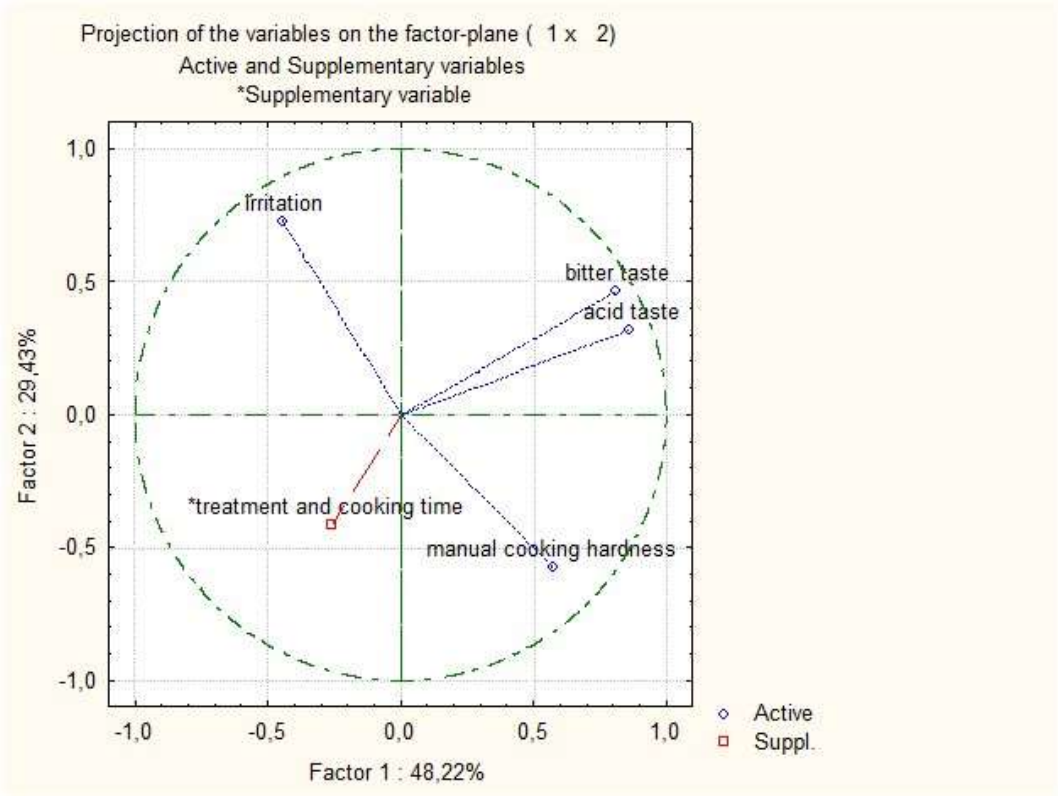


Figure 10 : variables contributions on the factor-plane (1x2)

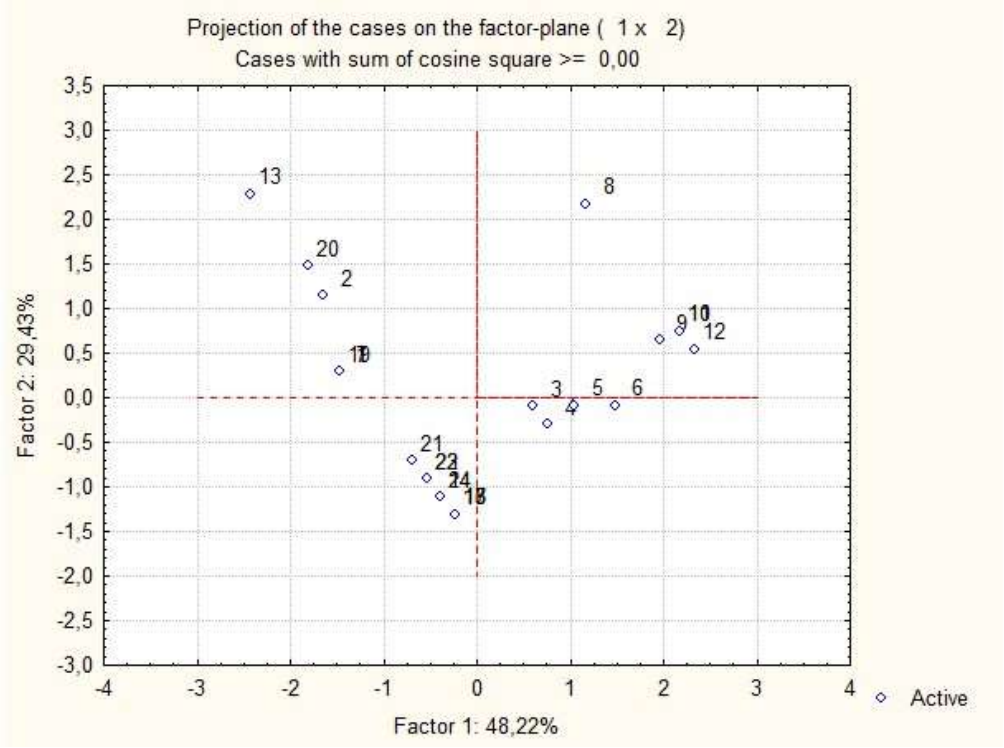


Figure 11 : spatial distribution of cooking times on the axis systems CP1 and CP2.