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Physico-chemical and microbiological characteristics of dried Waragashi

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In this study, effects of drying temperature on the physico-chemical and microbiological characteristics of Waragashi were investigated. Three types of produced Waragashi were investigated. The first one (V1) was obtained after coagulation of milk, the second called coloured Waragashi (V2), was obtained by boiling V1 for three minutes in aqueous solution of *Sorghum vulgare* panicle (15 g/L) and the third one, refined Waragashi (V3) was obtained by boiling for three minutes, the Waragashi V1 into aqueous solution of *S. vulgare* panicle (15 g/L), salt (10 g/L) and potash (3 g/L). The three fresh Waragashis contained 64.26, 57.34 and 54.04% moisture, respectively, for white Waragashi (V1), colored Waragashi (V2) and refined Waragashi (V3), while dried samples varied between 12.28 and 15.57%. The corresponding dried Waragashi were firmer than the fresh ones. Moreover, the colored cheeses (V2) were firmer ($60.08 \pm 5.40\text{N}$ and $206.4 \pm 13.70\text{ N}$) than the refined one ($38.57 \pm 3.10\text{ N}$ and $55.89 \pm 5.89\text{ N}$). After 48 h of drying, all samples showed a decrease of micro-organisms (mesophilic total bacteria, lactic bacteria, yeasts and moulds, *Enterobacteria* and *Staphylococcus* spp.) counts. However, drying at 45°C preserve more the physico-chemical characteristics of Waragashi.

Key words: Waragashi, cheese, drying, physico-chemical characteristics, microbiological quality.

INTRODUCTION

Due to the difficult conservation of the fresh cow's milk in developing countries, attempts of technological approaches were developed to transform it into added value products (Dossou et al., 2006). The production of cheeses provides a useful service by extending the shelf life of a valuable human foodstuff-milk.

Waragashi is Benin local dairy product that is widely consumed in rural as well as suburban and urban zones. The lack of standard processing methods explains the variations observed in quality of Waragashi in the different areas of production (Turkoglu et al., 1987, Belewu, 2004).

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Waragashi is an excellent source of protein, fat and minerals (calcium, iron and phosphorus), vitamins and essential amino acids. It is often consumed as a substitution to the meat and fish in various dishes (Kees, 1996).

In spite of its economic and nutritional importance, it is difficult to preserve Waragashi for a long time. Common traditional methods applied for preservation did not extend efficiently its shelf life. In order to increase the shelf life of Waragashi, a study on the preservation of this product by evaluating the effect of drying and vacuum packaging was carried out (Sacramento, 2008). As a result, Waragashi can be preserved during two months. However, the cost of the product makes the implementation of developed process difficult in economical point of view. Another work in Nigeria on wara cheese conservation focused on the effect of short-term frozen storage on the chemical composition and coliforms microflora was reported (Alalade and Adeneye, 2006).

It is well known, that the drying foods, preserves the shelf life of the products as well as the nutritive value and produces a new flavor (Shikha and Usha, 2012). In spite of the popularity of Waragashi in West Africa areas, few studies on appreciation of physico-chemical, technological and microbiological characteristics of dried Waragashi produced in Benin were investigated. The aim of present work was to evaluate the effect of temperature on physico-chemical, technological and microbiological characteristics of Waragashi cheese after drying.

MATERIALS AND METHODS

Preparation and drying of Waragashi

The milk used for the manufacture of Waragashi was collected at a Peulh camp at Abomey-Calavi. The collected cow milk was stored immediately in isothermal box containing ice in order to suppress the increase of microorganism population. The Waragashi was prepared according to the process developed by Dossou et al. (2006). The *Calotropis procera* leaves obtained from the University of Abomey-Calavi grounds were used to prepare the coagulant solution as describe by Dossou et al. (2006). The *Sorghum vulgare* panicle, the potash and salt were bought in a market of Godomey (Benin) and were used to color Waragashi. The produced Waragashi was drained and shaped on cylindrical box. The weight of the matrix was determined before and after 30 min of drainage with a portable electronic balance (Acculab Sartorius Group, Edgewood, NY, USA). Each Waragashi drained was cut into four parts and regrouped into three batches: the main one (Variety 1: V1), the coloured Waragashi (Variety 2: V2) and the refined Waragashi (Variety 3: V3).

The Waragashi V2 was obtained by boiling for three minutes the Waragashi V1 into aqueous solution of *S. vulgare* panicle (15g/L) while the Waragashi V3 was obtained by boiling for three minutes the Waragashi V1 into aqueous solution of *S. vulgare* panicle (15 g/L), salt (10 g/L) and potash (3 g/L). The three batches of Waragashi were closely followed during drying into electric oven (D 06060, model 400; MEMMERT, W 8540 Schwarbach, GmbH + CoKCT). The thermic drying at hot air was made into two temperatures during 48 h: 45°C (temperature 1: T1) and 60°C (Temperature 2: T2) through two batches. In total, 20 samples of

of Waragashi by batch were analyzed for physico-chemical, physical and microbiological analysis before and after 48 h of drying. The kinetics of the water loss vs. time was determined by the "drying characteristic curve" (DCC), which represents the drying rate $V(t)$ as a function of reduced water content ϕ . These two variables are defined as described by (Ahouannou et al., 2000):

$$\phi = \frac{X(t) - X_{eq}}{X_{cr} - X_{eq}} \quad \text{and} \quad V(t) = -\frac{dX}{dt}$$

$X(t)$: Dry basis product water content at time t , X_{eq} : dry basis product water content when equilibrium between air and product is reached, X_{cr} : dry basis product water content at the head of the first drying phase (initial phase with constant drying rate), $V(t)$: drying rate of product at time t , V_0 : drying rate of product during the first drying phase.

A mathematical expression of DCC for a product with specific initial dimensions is sought through the analysis of experimental drying curves obtained with different conditions of temperature, humidity and air drying speed. A representative example of such curves is shown in Figure 3, for the case of biological products. According to Jannot et al. (2002), the phase of raising temperature phase is most often negligible, especially if the difference between the air temperature and the product is low; and if the dimensions of the product are also low. Our experimental results are in concordance with this hypothesis.

The experimental curves $X(t)$ have been derived to obtain the estimated curves $V(t) = \left(-\frac{dX}{dt}\right)(t)$. Such analysis gives a mean value of the critical water content X_{cr} as shown in Figure 3. Several authors, among them, Desmorieux and Moyne (1992) have considered that for biological products it is difficult to identify a critical water content different from the initial water content X_0 . Thus, it is assumed equal, $X_{cr} = X_0$.

Physico-chemical analysis

Total solids content, ash and acidity were determined according to the methods described by AOAC (1990). Total sugar was determined according to the methods described by Dubois et al. (1959). Cheese samples were analyzed for pH values by using a digital pH-meter (Hanna Instruments, Model HI 98129, Singapore). The fat was extracted from cheese in a Soxhlet extractor with petroleum ether according to the methods described by Bligh and Dyer (1959) and Hubbard et al. (1977). The fat content was gravimetrically measured after the remotion of the solvent by rotary evaporation under vacuum (Bligh and Dyer, 1959). All physico-chemical analysis tests were conducted in triplicate.

Physical analysis

The texture was determined using a Stevens LFRA Texture Analyser (TA Instruments, USA) (Cayot et al., 2009) and the color through a chromameter Minolta Chroma CR-210 b (Minolta Camera Co. Ltd, Osaka, Japan). Analyses were done in triplicate.

Microbiological analysis of milk and various types of Waragashi

The analyses were achieved both on the milk and Waragashi. The count of mesophilic total bacteria, lactic bacteria, coliform bacteria, yeasts and moulds, and *Staphylococcus* spp. were evaluated. The plate count agar was used for the mesophilic total bacteria count

Table 1. Physico-chemical characteristics of milk.

Parameter	$\bar{x} \pm SD^a$
Relative density	1.02 \pm 0.01
Moisture (%) ^b	87.60 \pm 0.37
pH	6.78 \pm 0.05
Total acidity (%) ^c	0.19 \pm 0.02

^aMeans of three independent trials \pm standard deviation (SD). ^bThe water content was given in three repetitions according to the thermogravimetric method for the determination of the water content in food according to standard AOAC (1990). ^cTotal acidity by titration with NaOH 0.05 N until the indicator turn pink.

(Multon et al., 1994). The Man Rogosa Sharp medium (ISO 15214: 1998 (F)) was used for the lactic bacterias, the Malt Extract Agar (ISO 7954: 1987 (F)) for yeasts and moulds, the Violet Red Bile Agar for coliform bacterias count, according to the V 08-020 (1994)/ISO 7251 and V 08-021 (1993)/ISO 7402 norms (Bourgeois et al., 1989) and the Baird-Parker agar was used for *Staphylococcus* spp. count. For all microbiological analyses, samples of 25 g were taken from the cheese, transferred into 225 ml of the peptone water (% w/v) and homogenized. From the initial dilution, appropriate decimal dilutions were prepared and aliquots were plated in duplicate in the different mediums.

Mesophilic total bacteria count

One milliliter of each dilution was placed into each box after homogenization. 15 to 20 ml of the Plate Count Agar were smoothly added and kept at 45°C \pm 0.5 (Multon et al., 1994). After the solidification, the box was turned over and incubated at 30°C during 72 h.

Lactic bacteria count

One milliliter of each dilution was inoculated into each Man Rogosa Sharpe box (ISO 15214: 1998 (F)). The incubation was done at 30°C for three days.

Yeasts and moulds count

The selectivity of the malt extract agar was changed with the addition of lactic acid at 10% (sterilized previously at 121°C during 15 min) using a relationship of 100:2 ml. The incubation was done at 25 \pm 1°C for 5 days (ISO 7954: 1987 (F)).

Coliform bacteria counts

From the decimal dilutions taken from 10⁻¹ to 10⁻³, 1 ml in two boxes was introduced aseptically in two. About 20 ml of the Violet Red Bile Agar was added to the content of each boxes, melted and cooled at 45 \pm 1°C. The mixture was homogenized by a circular movement. A range of box was incubated at 30°C during 24 - 48 h so as to detect the total coliform and a second range is incubated at

44°C during 24 - 48 h to detected the fecal coliforms (Bourgeois et al., 1989).

The boxes incubated at 44°C were recovered; the germ that they contained was streaked onto Eosine Methylene Blue (EMB) and incubated at 37°C during 24 h in order to detect *E. coli*.

***Staphylococcus* spp. count**

0.1 ml of each dilution was inoculated onto the surface of the Baird-Parker agar, incubated at 37°C in aerobic conditions and the examination was achieved after 24 and 48 h.

Statistical analysis

The data obtained from these studies were analyzed using Statistical Analysis Software (SAS) and SPSS 17 (SPSS Inc. 233 South Wacker Drive, 11th Floor Chicago, IL 60606-641). The statistical analyses carried out were mean, standard deviation and analysis of variance (ANOVA) (Ogbeibu, 2005).

RESULTS

Physicochemical and microbiological characteristic of milk

Tables 1 and 2 show, respectively, the physicochemical and microbiological characteristic of the milk. The relative density (1.02 \pm 0.01), the moisture (87.60 % \pm 0.37), the pH (6.78 \pm 0.05) and the total acidity (0.19 % \pm 0.02) are very close to that listed in NF ISO 11816-1 (87%, 1.020 and 6.78, respectively for moisture, relative density and pH). The average of lactic bacteria, yeasts and moulds, Enterobacterias and *Staphylococcus* spp. counts for milk were determined and were, respectively, 5.30, 6.30, 1 and 0 log (CFU/ml), respectively, whereas the value of the mesophilic total bacteria count was lower (2.47 log CFU/ml) (Table 2). The mesophilic total bacteria and Enterobacterias counts were in concordance with the Institut Sénégalais de Normalisation (ISN) (1988) and Agence Française de Normalisation (AFNOR) (1976) criteria. However, the value of mesophilic total bacterias count found was higher than that advisable for commercialized milks by ISN (1988). Moreover, the negative results obtained from both tests of white side and blue methylene may confirm the good quality of the milk for the production of Waragashi.

Physico-chemical characteristics of Waragashi

Tables 3 and 4 show the characteristics of Waragashi produced (V1, V2 and V3) and the drying one (V1T1, V2T1, V3T1, V1T2, V2T2 and V3T2). The moisture content of Waragashi produced was 64.26, 57.34 and 54.04% respectively, for white Waragashi, coloured Waragashi and refined Waragashi (Table 3). Dried samples varied between 12.28 and 15.57%. As observed, during the analysis, the total sugar content of all Waragashi was statistically invariable and showed

Table 2. Microbiological quality (log CFU/ml)^a of milk.

Microbiological quality	Mesophilic total bacterial count	Lactic bacteria count	Yeasts and moulds count	Enterobacterial count	Staphylococcus spp. count	White side test	Blue methylene test
Milk used	< 2.47	5.30 ± 0.34	6.30 ± 0.34	1.00±0.00	Absence	-	-
Microbiological criteria (ISN, 1988)	4.30	*	*	2	Absence	*	*
Conformity	Conform	-	-	conform	conform	-	-

*Absence of criterion; -: Disregarded; ^aMeans of two independent trials (log CFU/ml) ± standard deviation (SD). I.S.N. (Institut Sénégalais de Normalisation).

Table 3. Physico-chemical characteristics* of Waragashi.

Waragashi	Dry matter (%) ¹	pH	Total Acidity (%db) ²	Total Sugar (%db) ³	Ash (%db) ⁴	Lipid (%db) ⁵
V1	35.74±0.11 ^a	6.70±0.00 ^d	0.12±0.00 ^b	5.75±0.11 ^a	2.06±0.04 ^a	47.26±0.001 ^f
V2	42.66±0.60 ^b	6.65±0.07 ^c	0.14±0.00 ^d	5.10±0.09 ^a	2.09±0.03 ^a	35.77±0.002 ^a
V3	45.96±0.05 ^c	6.60±0.14 ^b	0.15±0.00 ^b	5.64±0.08 ^a	2.17±0.06 ^a	36.88±0.001 ^b
V1 T1	85.64±0.01 ^d	6.15±0.07 ^a	0.20±0.04 ^c	5.40±0.27 ^a	3.75±0.01 ^b	50.86±0.09 ^h
V2 T1	87.72±0.47 ^f	6.35±0.07 ^b	0.16±0.02 ^d	5.42±0.23 ^a	3.78±0.13 ^b	43.80±0.067 ^e
V3 T1	87.53±0.87 ^f	6.45±0.07 ^b	0.14±0.05 ^b	3.25±0.27 ^a	4.09±0.13 ^b	48.30±0.42 ^g
V1 T2	86.42±0.75 ^e	6.50±0.00 ^b	0.05±0.01 ^a	5.81±0.17 ^a	4.66±0.12 ^c	42.61±0.28 ^d
V2 T2	85.04±0.51 ^d	6.40±0.00 ^b	0.07±0.00 ^a	2.57±0.10 ^a	4.54±0.08 ^c	39.35±0.39 ^c
V3 T2	84.43±0.98 ^d	6.45±0.07 ^b	0.13±0.00 ^a	2.60±0.14 ^a	4.67±0.05 ^c	50.09±0.71 ^h

*Means of three independent trials ± standard deviation (SD). 1, 2, 3, ... 5. Expressed as ... V1: White Waragashi, V2: Coloured Waragashi, V3: Refine Waragashi, V1T1: White Waragashi dry at 45 °C, V2T1= Coloured Waragashi dry at 45°C, V3T1: Refine Waragashi dry at 45°C, V1T2: White Waragashi dry at 60°C, V2T2 = Coloured Waragashi dry at 60°C, V3T2: Refine Waragashi dry at 60°C. The mean values followed by same letter in the same column are not significantly different (p< 0.05).

Table 4. Physical characteristics of Waragashi.

Waragashi	L* (brightness)	a* (red indicator)	b* (yellow indicator)	Strength (N)
V1	88.79±0.88	-1.98±0.042	13.12±0.49	7.01±0.48
V2	43.78±1.82	42.24±0.39	31.39±1.18	10.38±1.31
V3	37.49±1.19	32.98±0.72	19.63±0.73	10.2±0.13
V1T1	61.46±0.87	-2.89±0.22	13.63±1.15	43.58±4.92
V2T1	31.21±1.24	26.10±0.78	14.23±1.35	60.08±5.40
V3T1	26.41±0.815	17.03±0.76	4.03±0.84	38.57±3.10
V1T2	59.63±0.91	4.10±0.56	34.22±0.74	181.33±15.2
V2T2	31.22±0.75	25.10±1.18	20.78±0.43	206.4±13.70
V3T2	26.57±0.59	19.23±0.23	5.11±0.45	55.89±5.89
P	***	***	***	***

V1: White Waragashi, V2: Coloured Waragashi, V3: Refine Waragashi, V1T1: White Waragashi dry at 45°C, V2T1: Coloured Waragashi dry at 45°C, V3T1: Refine Waragashi dry at 45°C, V1T2: White Waragashi dry at 60°C, V2T2: Coloured Waragashi dry at 60°C, V3T2: Refine Waragashi dry at 60°C, P: Probability; (***) = great variability (level: 1%) in the same column.

values between 2.57 and 5.75% (db) (dry base).

On the other hand, the total acidity content of the produced Waragashi (V1, V2 and V3) was statistically

equal to that of the dried sample at 60°C. The total acidity content of the Waragashi varied between 0.12 and 0.15 % (db), the samples dried at 60°C varied between 0.05

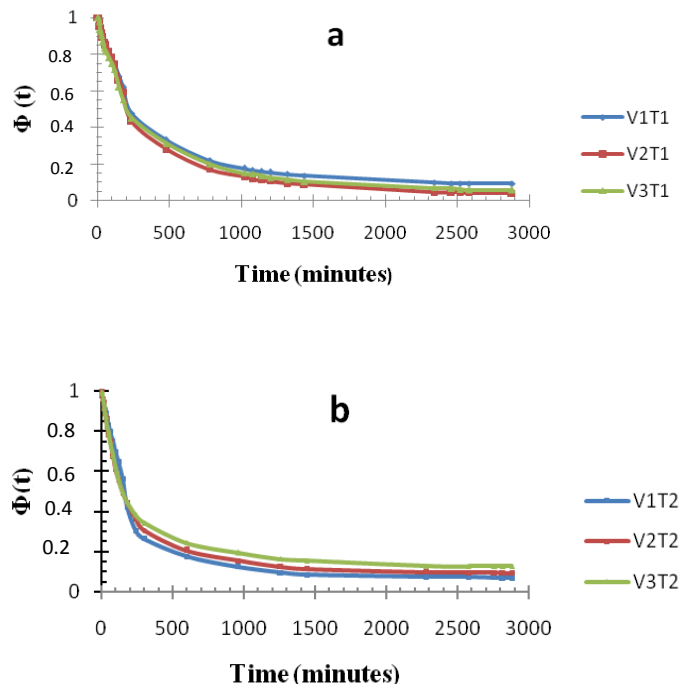


Figure 1. Kinetics of the reduced moisture of Waragashi (white, colored and refined) dried at 45 (a) and 60°C (b).

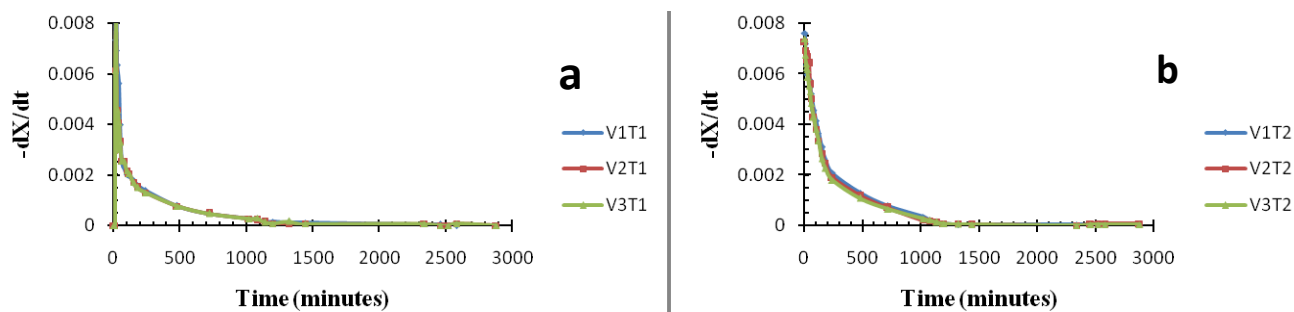


Figure 2. Kinetics of drying speed of waragashi (white, colored and refined) at 45°C (a) and 60°C (b).

and 0.13% (db). The ash content of the Waragashi (V1, V2 and V3) was statistically equal and varied between 2.06 and 2.17% (db). Likewise, the ash content of the dried samples were statistically equal and varied between 3.75 and 4.09% (db) and between 4.54 and 4.67% (db) for the dried samples at 45 and 60°C, respectively. As clearly shown in Table 3, the lipid content of Waragashi varies accordingly with the variety and the drying temperature.

The results of the texture and the color characteristics of fresh and dried Waragashi (Table 4) showed a great variability (level: 1 %) between the two types of cheese. Meanwhile, Waragashi V1 had a great brightness (88.79 ± 0.88), low red indicator (-1.98 ± 0.042) and low yellow indicator (13.12 ± 0.49). This cheese is less firm (7.01 N) than the colored (10.38 N) and the refined (10.2 N) ones. The colored sample was redder (42.24 ± 0.39)

and lighter (43.78 ± 1.82) than the refined sample (32.98 ± 0.72 , 37.49 ± 1.19 , respectively for red indicator and brightness).

The brightness of dried sample varied between 59.63 and 61.46 for Waragashi V1 dried at 45 and 60°C, while those from V2 and V3 varied between 26.41 and 31.22. On the other hand, the dried cheeses were firmer than the fresh one.

Moreover, colored cheeses (V2) were firmer (60.08 ± 5.40 and 206.4 ± 13.70) than that of the refined one (38.57 ± 3.10 and 55.89 ± 5.89) at 45 or 60°C.

Kinetic of drying

Figures 1, 2 and 3 present the kinetic of reduced moisture of Waragashi, the kinetic of drying speed of

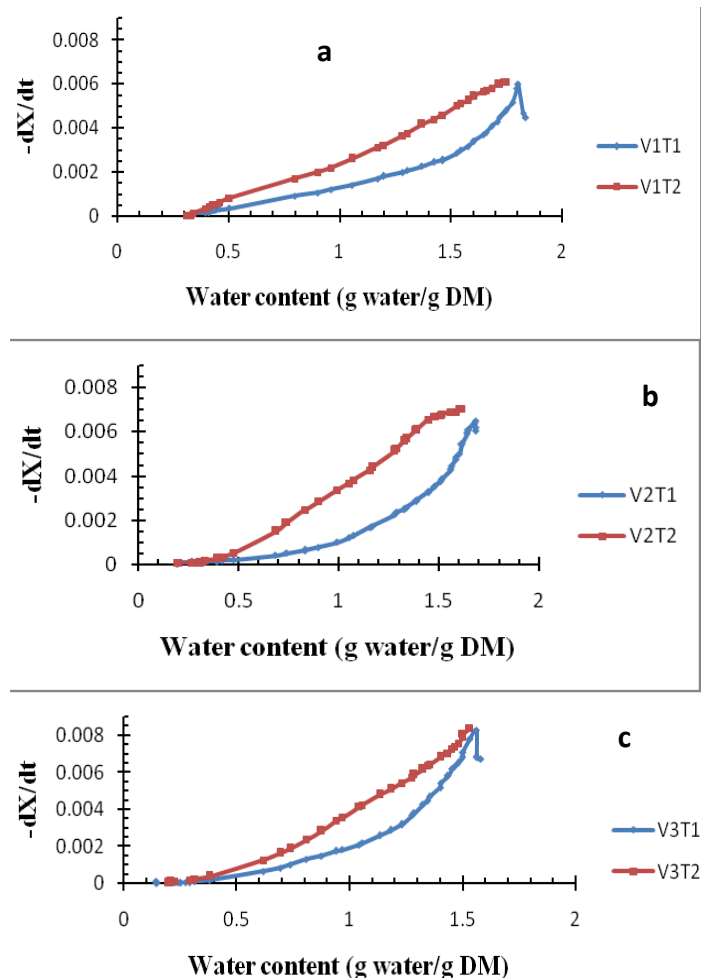


Figure 3. Kinetics of drying speed of samples (white (a), colored (b) and refined (c)) at 45 and 60°C.

Waragashi and kinetic of evolution of drying speed of samples.

From the results of the Figures 1a and b, the plots are leading as typically observed on biologic product like food. The plot present two principal phases, in the first part, corresponding to the 24 h of drying, the moisture decreased rapidly followed by a less fast decreased phase. The average moisture of fresh samples and dried one at 45°C (Figure 1a), respectively, were 1.837 and 0.147 g water/g DM (db) for white cheese, 1.684 and 0.129 g. water/g DM (db) for colored cheese and 1.595 and 0.132 g water/g DM (db) for the refine one. However, statistically there is the significant difference (5%) between the declines of moisture of all samples from the eighteenth to forty-eighth hour at the end of drying. The average moisture of fresh samples and dried one at 60°C (Figure 1b) were 1.897 and 0.167 g water/g DM (db) for white cheese, 1.642 and 0.176 g water/g DM (db) for the colored cheese and 1.579 and 0.201 g water/g DM (db) for the refine sample.

Static analyses showed a significant difference (5 %) between the declines of moisture of all samples from 16 to 48 h by the end of drying. Figure 2a and b show the evolution of the drying speed at 45 and 60°C of white, colored and refined Waragashi. During the 10 first min of drying at 45°C, no evolution was observed (Figure 2a) but after twenty minutes of drying, there was a maximal average of 0.0086 g water/g DM.min⁻¹ for Waragashi V1 and speed of 0.0080 g water/g DM.min⁻¹ for Waragashi V2 and V3. Later on, the speed began to decrease until the end of the process.

However, the analysis of variance did not show a significant difference between the drying' speeds of the three cheeses from the beginning to the end of the process. The evolution of speed of each variety of cheeses was also investigated (Figures 3a, b and c). From the results of Figure 3, the average speed of the elimination of water was 0.006 g water/g DM x min⁻¹ for drying at 45°C and was 0.007 g water/g DM x min⁻¹ for 60°C.

Table 5. Microbiological quality (CFU/g)^a of Waragashi fresh with respect to the Food Safety Consult (F.S.C.) (2005) criteria.

Waragashi	Mesophilic total bacteria count	Lactic bacteria count	Yeasts and moulds count	Enterobacterias count	<i>Staphylococcus</i> spp. count
V1	2.30 ± 0.21	3.30 ± 0.24	2.60 ± 0.24	1	< 1
V2	1.78 ± 0.07	1.70 ± 0.18	1.30 ± 0.00	< 1	< 1
V3	1.70 ± 0.08	1.30 ± 0.24	1.48 ± 0.36	< 1	< 1
Microbiological criteria	*	*	*	< 2	< 2
Level of conformity of the samples (%)	-	-	-	100	100

V1: White Waragashi, V2: Coloured Waragashi, V3: Refine Waragashi *: Absence of criterion; -: Disregarded; ^aMeans of two independent trials (log CFU/ml) ± standard deviation (SD).

Table 6. Microbiological quality (CFU/g)^a of Waragashi dried with respect to the AFNOR criteria (1994).

Waragashi	Mesophilic total bacterial count	Lactic bacterial count	Yeasts and moulds count	Enterobacterias count	<i>Staphylococcus</i> spp. count
V1 T1	< 1.30	1.60 ± 0.11	1.70 ± 0.49	< 1	< 1
V2 T1	< 1.30	1.60 ± 0.24	1.30 ± 0.24	< 1	< 1
V3 T1	< 1.30	1.48 ± 0.17	1.00 ± 0.00	< 1	< 1
V1 T2	< 1.30	1.48 ± 0.36	1.48 ± 0.24	< 1	< 1
V2 T2	< 1.30	1.60 ± 0.43	1.00 ± 0.00	< 1	< 1
V3 T2	< 1.30	1.48 ± 0.00	1.48 ± 0.36	< 1	< 1
Microbiological criteria	3	2	2	2	2
Level of conformity of the sample (%)	100	100	100	100	100

V1T1: White Waragashi dry at 45°C, V2T1: Coloured Waragashi dry at 45°C, V3T1: Refine Waragashi dry at 45°C, V1T2: White Waragashi dry at 60°C, V2T2: Coloured Waragashi dry at 60°C, V3T2: Refine Waragashi dry at 60°C. ^aMeans of two independent trials (log CFU/ml).

Microbiological quality of Waragashi

Table 5 shows the microbiological quality of the produced Waragashi. The average of mesophilic total bacteria, lactic bacteria, enterobacteria and yeasts and moulds counts for white Waragashi (V1) were 2.30, 3.30, 1 and 2.60 log(CFU/g), respectively, while *Staphylococcus* spp. counts were lower (1 log(CFU/g)). Roughly, there is a decimal decreasing of micro-organism in pre-treated cheeses (V2 and V3) and, after 48 h of drying, all the samples present a decrease of micro-organisms and were in concordance with AFNOR (1994) criterias (Table 6).

DISCUSSION

It is well known that during drying of foods, bio-chemical changes such as glycolysis, proteolysis, and lipolysis take place by the modification of composition of the product and enhancing the characteristics features to

foods, especially the texture and flavour. The analysis of variance (Table 4) shows that the colored and the refined Waragashi (V2 and V3) were firmer (10.38 and 10.2 N, respectively) than the white cheese ($p < 0.05$). The variations observed may be due to the infiltration of the molecules of color in white cheese during coloration and refining.

In fact, the infiltration of these may form a film of solution which decreases the moisture content of white cheese from 64.26 to 57.34% after coloration by a gradient of density (Table 3). The use of salt and potash may concentrate coloring molecule and increase gradient of density. This observation justifies the decrease of moisture of refined cheese (54.04 %).

The decrease of moisture is physically expressed by the firmness of Waragashi as reported in several works in the literature (Mazou et al., 2012). Mazou et al. (2012), Sacramento (2008) and Kora (2005) suggested that the use of salt and potash favored the decrease of moisture and increase the texture of the cheeses.

The colored cheeses had great red and yellow indicator

($a^* = 42.24$, $b^* = 31.39$) comparatively to the refined cheese ($a^* = 32.98$, $b^* = 19.63$, $p < 0.05$) whereas the white cheeses had low red and yellow indicator ($a^* = -1.98$; $b^* = 13.12$, $p < 0.05$) (Table 4). In this result, the sorghum panicle colors the cheese red while potash concentrates the red coloration and turn slightly on black as reported by Sacramento (2008) and Mazou et al. (2012). The dried white cheese had statistically a comparable brightness ($L^* = 61.46$ and $L^* = 59.63$, respectively for 45 and 60°C). This result showed that the temperature of 45 and 60°C did not influence the brightness of Waragashi. However, the temperature of 60°C browned the white cheeses and draws the lipid up.

On the other hand, the interval between 45 and 60°C did not affect the red indicator and the brightness of colored cheese. The brightness, the red and the yellow indicators of the refined cheeses after drying drop significantly when the temperature increases from 45 to 60°C (Table 4). Generally, the dried cheeses are firm when the temperature increases. This result confirms those of Sacramento (2008) who reported that fresh Waragashi were less firm and more friable than the dried one and were easily transportable and marketable (Shaffer, 1998).

The dry matter, pH, total acidity, sugar and ash Waragashi were similar to those reported by Mazou et al. (2012). But the sugar content is lower than that observed by Kora (2005). Ultimately, the statistical results of the three varieties of Waragashi, showed that pH, total acidity, sugar content and the ash content of the three varieties of Waragashi are similar. This shows that the pretreatment does not affect the physicochemical characteristics of colorful and refined Waragashi over the white Waragashi.

The lipid contents of colored and refined Waragashi (35.77 and 36.88%, respectively) are lower than those from white Waragashi (47.26%). This reduction in the lipid content of pretreated Waragashi can be explained by the loss of lipid during cooking and coloring operations.

The dry matter of white Waragashi dried at 45 and at 60°C (85.64 and 86.42%, respectively) does not exceed 5% of difference and the moisture contents (14.36 and 13.58%, respectively) were closed to the equilibrium moisture content values (15%) of dried foods (BIT, 1990). The temperature range 45 - 60°C therefore does not affect the moisture content of the dried white Waragashi and reaches the equilibrium of water content (15%) in dried foods. However, the apparent acidity and the ash content varied significantly between fresh white samples dried Waragashi at 45 and dried at 60°C. The significant change in the ash content due to the degradation of the material justifies the significant variation in the pH of white Waragashi. There was a certainly production of acid by lactic bacteria during the drying of white Waragashi. In general, the temperature range 45 - 60°C is suitable for drying white Waragashi. Statistical analysis showed that the dry matter content and sugar content of

white Waragashi dried at 45°C and those dried at 60°C are similar. However, pH and ash content of Waragashi samples dried at 45°C respectively, 6.15 and 3.75% are lower than that of the dried samples at 60°C, respectively, 6.50 and 4.66%. The best drying temperature (45°C) for dried white Waragashi was similar to that of fresh white Waragashi. Meanwhile, the temperature of 60°C does not contribute to preserve pH and ash content of Waragashi but decreases the lipid content.

The plot of instantaneous evolution of reduced moisture of Waragashi (Figure 1), confirms the assertion that the infiltration of colored molecules on the colored and refined cheese decreases the moisture content and the facility of evaporation of water by drying at 60°C (Figure 1b). In fact, the reduction of moisture increases with the increase of temperature as observed by Silva et al. (2011). The required drying time to reduce the moisture of white Waragashi at an inferior or equal value of 0.20 g water/g DM were between 44 and 48 h, respectively of thermic drying for the samples dried at 60 and 45°C. The decrease of drying time with the augmentation of the temperature of drying was also observed by Lagunas (2007). However, the pre-treatment of white Waragashi did not affect the speed of drying (Figure 2). As shown in Tables 5 and 6, the produced Waragashi showed lower mesophilic total bacteria and *Staphylococcus* spp. counts than those detected in the milk. This finding confirms the destruction of the micro-organisms by heat. On the other hand, the count of yeasts and moulds in Waragashi were higher than that recommended by the AFNOR (1976) norms, which maintain these counts at a level than 1 log(CFU/ml) (Guiraud and Galzy, 1980). During samples drying, significant decrease of germs was observed, as reported also by Sacramento (2008) on Waragashi drying. The increase of temperature inhibited the development of most germs, as observed in this work during storage of Waragashi.

Conclusion

The effect of the drying temperature (45 and 60°C) preserves the physico-chemical characteristics of Waragashi, and the multiplication of microorganisms. However, drying at 45°C preserve more the physico-chemical characteristics of Waragashi due to the fact that it maintains the physico-chemical and technological characteristics of Waragashi close to the fresh one.

Conflict of interests

The authors did not declare any conflict of interests.

REFERENCES

- AFNOR (1976). Critères microbiologiques AFNOR de référence concernant les fromages frais pasteurisés à la distribution (Journal officiel des communautés européennes du 31 janvier 1973,

- règlement 455/7).
- AFNOR (1994). Critères microbiologiques sur les fromages au lait cru ou au lait thermisé. Agence Française de Normalisation. Arrêté du 30 mars 1994 publié au Journal Officiel du 21 avril 1994.
- Ahouannou C, Lips B, Jannot Y, Lallemand A (2000). Caractérisation et modélisation du séchage de trois produits tropicaux : manioc, gingembre et gombo. *Sciences des aliments* 20:413-432.
- Alalade OA, Adeneye JA (2006). The effect of storage period on the chemical composition and coliform microflora of Wara cheese. *J. Dairy Sci.* 1(2):126-130.
- AOAC (1990). Official Methods of Analysis, Association of Official Analytical Chemist Inc. Virginia, USA.
- Bligh EG, Dyer WJ (1959). A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37:911-917.
- Bourgeois CM, Mesclé JF, Zucca J, Larpent JP (1989). *Microbiologie alimentaire*. 2 volumes. Paris, Technique et Documentation, Lavoisier.
- Cayot P, Gautier L, Soubrier J (2009). Définir, dénommer et traduire l'onctuosité : regards croisés sur une propriété gustative et ses dénominations en français, en anglais et en allemand in Danièle Beltran-Vidal (Ed.). *Les mots de la santé (2) : affaires de goût*. Lyon : CRTT.
- Dossou J, Hounzangbe-Adote S, Soulé A (2006). Production et transformation du lait frais en fromage peulh au Bénin: Guide de bonnes pratiques, avec l'appui financier de la coopération française et du GRET. pp. 23-33.
- Dubois MKA, Gilles YK, Hamilton PA (1959). Colorimetric method for determination of sugars and related substance. *Anal. Chem. J.* 28: 350-356.
- Guiraud J, Galzy P (1980). L'analyse microbiologique dans les industries alimentaires, collection Génie alimentaire. pp. 81-83.
- Hubbard WD, Sheppard AJ, Newkirk DR, Prosser AR, Osgood T (1977). Comparison of various methods for the extraction of total lipids, fatty acids, cholesterol and other sterols from food products. *J. Am. Oil Chem. Soc.* 54:81-83.
- ISN (1988). Les normes microbiologiques : lait et produits laitiers. Dakar, Institut Sénégalais de Normalisation (ISN/CT3/SCT4).
- Kees M (1996). Le fromage peulh: Facile à produire et bien apprécié. Une technologie à vulgariser. Rapport de Recherche/GTZ 10-23:59-70.
- Kora S (2005). Contribution à l'amélioration de la technologie de production du Waragashi au Bénin. Thèse d'Ingénieur Agronome. Université d'Abomey-Calavi, Bénin, 105p.
- Lagunas LM (2007). L'effet des conditions variables de séchage thermique sur la cinétique de séchage thermique et la qualité de l'ail, Thèse, Département des sciences des aliments et de nutrition, Faculté des sciences de l'agriculture et de l'alimentation, Université Laval, Québec.
- Mazou M, Tchobo P, Degnon G, Mensah A, Soumanou MM (2012). Effect of temperature and salt on the quality of Waragashi during storage in Benin Republic. *Afr. J. Food Sci.* 6 (20): 494-499.
- Multon JL, Arthaud JF, Soroste A (1994). La qualité des produits alimentaires, Tec & Doc, 2^e édition, 753 p.
- Ogbeibu AE (2005). Biostatistics, a practical approach to research and data handling. Mindex Publishing Company Ltd., Benin City, Nigeria p. 264.
- Sacramento ORH (2008). Contribution à l'amélioration de la conservation du Waragashi par l'effet combiné du séchage et de l'emballage sous vide. Département de Nutrition et Science Alimentaire. Faculté des Sciences Agronomique, p. 60.
- Shaffer M (1998). Food drying. Backwoods home magazine. 39 p.
- Shikha M, Usha B (2012). Effect of heat treatment on the storage stability of low calorie milk drinks. *J. Food Sci. Technol.* DOI 10.1007/s13197-012-0714-z.
- Silva MAC, Gomes Corrêa JL et Silva ZE (2011). Drying kinetics of west indian cherry: influence of osmotic pretreatment, B.CEPPA, Curitiba. 29(2):193-202.
- Turkoglu N, Litopoulou-Tzanetakis A, ManolkidisK (1987). Microbiology of Kopanisti, a traditional Greek cheese. *Food Microbiol.* 4:92-94.