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CHANGES IN THE PROPERTIES OF UHT WHEY-BANANA BEVERAGE DURING STORAGE

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ABSTRACT

Changes in the physical characteristics of Ultra High temperature (UHT) and non-UHT treated whey-banana beverages were determined for samples stored for 1, 3, 10 and 17 days at 4°C, 20°C, 30°C and 40°C. Sedimentation was greater for the non-UHT whey-banana beverage and increased with increasing storage temperature. The flow behavior and consistency indexes were comparable for both UHT and non-UHT treated samples.

While the flow behavior decreased with increasing storage temperature, the consistency increased. At 17 days, the volume mean diameter (D_{43}) was greater for the UHT beverages at all storage temperatures. However, the surface area mean diameter (D_{32}) was greater for the UHT beverages and independent of time and temperature. Except for the color value "H*" which was significantly high for the non-UHT product, the color values a*, b*, c* and L* were greater for the UHT beverages over the ten day storage period at all temperatures 4°C, 20°C, 30°C and 40°C.

Keywords: *UHT processing, color, whey-banana beverages, polyphenols, browning, storage temperature*

RÉSUMÉ

Evolution des boissons à base de banane fortifiées au lactosérum après pasteurisation

Des changements au niveau des caractéristiques physiques ont été mesurés des boissons fortifiées au lactosérum avant et après pasteurisation lors d'un entreposage de 1, 3, 10 et 17 jours à 4°C, 20°C, 30°C et 40°C. Le dépôt était plus important dans la boisson n'ayant pas subi de traitement thermique et s'accrut avec l'élévation de la température d'entreposage. L'indice de fluidité et le coefficient de consistance étaient identiques pour les deux types de boissons. Tandis que l'indice de fluidité chutait avec l'augmentation de la température d'entreposage, la consistance s'élevait.

Après 17 jours, le diamètre moyen des particules ($D_{4,3}$) était plus grand dans la boisson pasteurisée quelle que soit la température d'entreposage. Le diamètre des particules était aussi indépendant du temps et de la température d'entreposage. Excepté le paramètre de couleur 'H', plus élevé pour la boisson non pasteurisée, les autres paramètres de couleur que sont a*, b*, c* et L* étaient plus élevés pour la boisson pasteurisée pendant les 10 jours d'entreposage aux températures employées (4°C, 20°C, 30°C et 40°C).

Mots-clés : *Procédé UHT (Ultra Haute Température), couleur, boissons fortifiées au lactosérum, polyphénols, brunissement, température d'entreposage*

I - INTRODUCTION

Ultra high temperature (UHT) (~140-145°C/ 4-10 sec) treatment of whey products is required for sterility in aseptic packaging systems. However, whey proteins denaturation is inevitable, and precedes a number of changes taking place during storage [1]. Beta-lactoglobulin (β-lg) and alpha-lactalbumin (α-lac) are the most abundant whey proteins that influence the functional properties of the heated product. Several factors including protein concentration, pH, total solids and mineral contents influence the denaturation process [2].

The effect of pH on the whey proteins has been studied and reports showed that β-lg was less stable at alkaline pH, whereas α-lac stability was independent in pH range 3 to 7.5 [3]. However, sulfhydryl group-disulfide bond interchange reactions was demonstrated at ambient temperature and under acidic conditions (pH~ 4.5) [4]. An increase in viscosity of skim milk upon heating and before gel formation during storage of milk products as well as factors affecting gel formation has been documented [5].
All the sulphydryl groups became reactive after UHT treatment [6]. Intra or intermolecular reaction of β-lg with κ-casein or the proteins of the milk fat globule membrane can induce the formation of a three-dimensional protein network which causes the milk to thicken and gel. An increase in viscosity

after heating milk product was due to unfolding of β-lg and polymerization products that acted as sticky agents between casein and stainless steel to form a fouling layer [7]. More severely heated milks (indirect heat) showed resistance to gelation due to the fact that processing mode takes place in the presence of oxygen which has been found to be a chain reaction break on thiol-disulfide exchange reactions [5]. Thus, polymerization and denaturation of β-lg is slowed by oxidation of thiol groups to disulfides. However, the direct steam injection removes oxygen from the product and UHT milk using this method contains less denatured whey protein attached to casein micelles (and gels faster) than indirectly heat-treated milk [8].

Changes in milk composition including protein concentration, pH, total solids concentration and minerals influence thermal stability and heat-induced interactions of whey proteins [9-11]. Milk undergoes chemical changes during storage, via the Maillard reaction between lactose and the ε-NH_2 groups of lysine residues [12] .The Maillard reaction proceeds during storage and affects the physical and nutritional properties of the product [13].

Polyphenol-rich extracts of tea (green and black), red wine, cocoa powder, coffee, coconut shell and oak leaves increased the heat stability of skim milk and concentrated skim milk as well as the rennet coagulation time of milk [14,15]. Pectins prevent protein aggregation during heat processing by adsorbing onto the surfaces of the proteins and acting as a dispersing agent in acid milk drinks [16]. Interaction between pectins and other components of heat processed beverages is likely to affect the physical properties of products. Previous work with UHT whey-banana beverages have shown that particle size and whiteness did not change over a 60 day storage period at 4°C, 20°C, 30°C and 40°C even though sedimentation and serum separation was observed [17]. Protein aggregation and particle growth is an undesirable defect observed in milk beverages after heat processing.

In banana-producing countries where malnutrition prevails, development of a nutritious, shelf-stable whey-banana beverage is a potential way to utilize surplus banana fruit. Whey proteins possess more sulphur containing amino acids than casein, as well as a surplus of the essential amino acids, which are often limited in plant proteins. There is a need to better understand the contribution of UHT process to the stability characteristics of the whey-banana beverages. The objective of this work was to examine the effect of UHT treatment on the particle size, rheological, optical, properties and stability parameters of whey-banana beverages stored at varying temperatures between 4 and 40 ^{O}C. A control with no heat treatment was used to provide information about the intrinsic developments in the beverages.

II - MATÉRIEL ET MÉTHODES

II-1. Materials

Whey protein concentrate (80 % protein) was obtained from Protient (Lot code LUV 1225 St. Paul, MN). High methoxyl pectin (50 % uronic acid, 80 % DE, Genu pectin type JMJ) was provided by Hercules (Wilmington, DE) and acidified banana puree was donated by Chiquita (Chiquita Brands, Inc., Cincinnati, OH).

II-2. Preparation of UHT and non-UHT whey-banana beverages

A blend of 1 part of banana puree to 2 parts of acidified (20 % citric acid to pH 4.0) water and whey protein (5 %) was prepared in a surge tank with agitator and aseptic homogenizing valve of the N0-BAC Unitherm IV processing system (Cherry-Burrel Amc International, IA) as described by Shekilango [18]. Sucrose (15 % w/w) and pectin (0.15 % w/w) were dry-mixed and added to the whey and citric acid while stirring. The mixture was homogenized at 3000 psi and heated for 5-7s at 140°C with the indirect heating method. The UHT processed beverages were filled into pre-sterilized 450 ml glass bottles and stored at 4°C, 20°C, 30°C and 40°C for 1, 7 and 17 days for further analyses. The non-UHT product was processed and stored under the same conditions without the heating step.

II-3. Color

The color of the UHT and non-UHT whey banana beverages were evaluated using a Minolta Chroma meter (CR-200/CR-231; Minolta, Japan) which determines the a* (green/red), b* (blue/yellow), c* (chroma), H* (hue) and L* (whiteness or luminosity) values [19].

II-4. Rheology

A Dynamic Stress Rheometer (Rheometrics, Piscataway, NJ) was used to determine the flow behavior and consistency indexes of the UHT and non-UHT whey-banana beverages. The couette geometry (cup diameter = 32.0 mm, bob diameter = 29.5 mm, and bob length = 44.5 mm.) was used. A steady stress sweep test was conducted to determine the flow behavior data at 10°C with an initial and final rate of 10 (sec^{-1}) and 100 (sec^{-1}) respectively with a measurement time of 10 seconds at each shear rate [20].

II-5. Particle size

Particle size distribution of the UHT and non-UHT whey-banana beverages is determined by laser diffraction using a Malvern Mastersizer (Worcestershire, UK); Samples of banana beverages were introduced in the sample unit containing deionized water and pumped through the optical cell (code for optical properties of the particles, "presentation", 3ODH) while stirring at 2,000 rpm. Size distribution (volume and surface area mean diameters) were estimated and expressed as $D_{4,3}$ and $D_{3,2}$.

II-6. Sediment

Centrifugation of the UHT and non-UHT whey-banana beverages were performed and supernatants were separated after centrifugation at 3000 x g (Marathon 3200, Fisher Scientific, Pittsburgh, PA) for 20 minutes at ambient temperature and weighed after draining for 10 minutes. The relative weight of the pellets was reported as an indication of stability.

II-7. Serum separation

Samples were placed in 5 ml disposable pipettes sealed at both ends and incubated at 4°C, 20°C, 30°C and 40°C to assess serum separation under gravity. The pipettes were inspected at various time intervals within 17 days. When sedimentation occurred, a layer of clear supernatant was left at the top and volume of this was recorded as an indication of instability. The % volume of serum separated from the total volume was reported.

II-8. Statistical analysis

Analysis of variance of the data was applied according to a factorial design with temperature and storage time nested within processing mode (UHT / non-UHT treatment). Interaction between storage time used as covariate and the processing mode (treatment) was checked for significance before running the analysis. Differences between UHT and non-UHT treatment means were determined by the Tukey's procedure at $p < 0.05$ using the Statistical Analysis System software (SAS Inc., NC).

III - RESULTS AND DISCUSSION

The analysis of variance for data collected at 1, 3, 10, and 17 days indicate that there were significant interactions ($p < 0.05$) between time, temperature, and heat treatment ***(Table 1)***. Therefore, comparisons between processing mode (UHT/no UHT) were made at each time and temperature.

Table 1 : *.Summary of Anova data for factors influencing the physical properties of UHT and non-UHT whey-banana beverages*

Factors	% Sed[4]	n[5]	K[6]	[7]D_{43}	[8]D_{32}	a*[9]	b*[10]	c*[11]	H*[12]	L*[13]
Main effects										
Process[1]	S****	NS	S****	S****	S****	S****	S****	S****	S****	S****
Time[2]	NS	S****	S****	NS	S*	S****	S****	S****	S****	NS
Temp[3]	S****	S****	S****	S****	NS	S****	S****	S****	S****	S****
Inter-actions										
Process/ Time	S****	NS	S*	NS	NS	S****	S****	S****	S****	S**
Process/ Temp	S****	S***	S*	S****	NS	S****	S****	S****	S****	S****
Time/ Temp	S*	S****	S****	S*	S**	S****	S****	S****	S****	S****
Process/ Time/ Temp	S**	NS	S***	S****	NS	S****	S****	S****	S****	S****

*S**** represents a significant effect at $p < 0.0001$,*
*S*** represents a significant effect at $p < 0.001$,*
*S** represents a significant effect at $p < 0.01$,*
S represents a significant effect at $p < 0.05$,*
NS indicates no significant effect ($p \geq 0.05$).

[1]The processing mode (UHT or not UHT), [2]Storage time, [3]Storage temperature, [4]Sedimentation (% w/w), [5]Flow behavior index, [6]Consistency coefficient, [7]Particle volume mean diameter, [8]Particle surface area mean diameter, [9]redness, [10]yellowness, [11]Chroma, [12]Hue, [13]Whiteness.

III-1. Sediment

The data in ***Figure 1*** show the plot of sediment versus storage time and storage temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance ***(Table 1)*** showed that heat treatment and storage temperature were the major factors influencing sedimentation. Storage time effect was not significant. The interactive effects of heat treatment-storage time, heat treatment-storage temperature, storage time-storage temperature, heat treatment-storage time-storage temperature were significant. Sedimentation was highest at 40°C for both UHT and non-UHT whey banana beverages. At day one the non-UHT whey-banana beverage exhibited significantly ($p < 0.05$) higher sedimentation percentage than the UHT treated whey-banana beverage at all storage temperatures. At day 3, the non-UHT beverage exhibited significantly ($p < 0.05$) higher sedimentation than the UHT beverages at 4°C, 20°C and 30°C. Sedimentation was comparable in the non-UHT and UHT beverages stored at 40°C for 3 days. At ten or seventeen days, the non-UHT beverage showed significantly ($p < 0.05$) higher sedimentation compared to the UHT beverages at any of the four temperatures 4°C, 20°C, 30°C and 40°C.

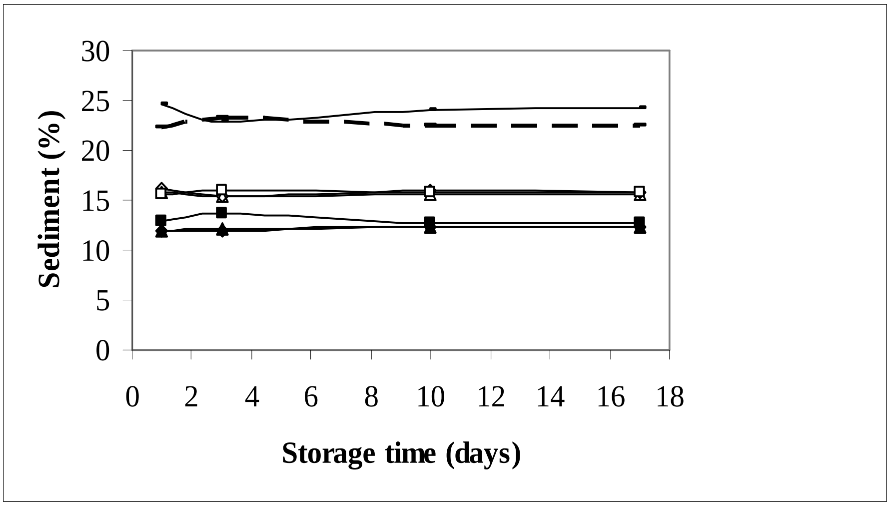

Figure 1 : *% Sediment measured after centrifugation (3000 x g, 20 min) of whey-banana beverage (12 g sample size) as a function of storage time.*

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at 4^{O}C,*
(▲) *UHT treated whey-banana beverage stored at 20^{O}C,* (Δ) *non-UHT treated whey-banana beverage stored at 20^{O}C*
(■) *UHT treated whey-banana beverage stored at 30^{O}C,* (□) *non-UHT treated whey-banana beverage stored at 30^{O}C,*
(▬ ▬) *UHT treated whey-banana beverage stored at 40^{O}C,* (C) *non-UHT treated whey-banana beverage stored at 40^{O}C.*

Destabilization is most likely to occur in pasteurized acid milk beverage compared to the non-pasteurized beverage [21]. Storage time of whey-banana beverages did not significantly affect sediment generation in UHT milk, nor the non-UHT milk ($p > 0.05$). The difference in the amount of sediment for the UHT and non-UHT beverages could be due to a mechanism similar to the fouling phenomenon observed in whole milk during processing [22]. According to this author, the material available for sedimentation in whole milk will appear in the carton only if it does not burn or deposit on the interior of the heat exchanger. Both UHT and non-UHT whey-banana beverages contain sedimentable material; however, possible fouling in the UHT system left less material available for sedimentation in the UHT treated beverages.

III-2. Rheology

The plot of the mean values for the flow behavior index for all data collected at each storage period and temperature for UHT and non-UHT treated whey-banana beverages is presented in ***Figure 2***. The analysis of variance of the data (Table 1) showed that time and storage temperatures were the major factors influencing flow behavior. The time effect was strongly dependent on the storage temperature. There was no significant effect due to heat treatment ($p > 0.05$).

The interactive effects of heat treatment-storage period-temperature were not significant ($p > 0.05$). The flow behavior of the UHT and non-UHT beverages stored at 40^{o}C exhibited significantly ($p < 0.05$) lower flow behavior indexes (~ 0.4) than the beverages stored at all 3 lowest temperatures with flow indexes close to 0.6. Differences if any between UHT and non-UHT beverages were observed only at the beginning of storage (day one) and disappeared during the rest of the storage period.

The decrease in flow behavior index at 40°C compared to 4°C , 20°C or 30°C could be due to the enhancement of the interaction between pectin and whey proteins at the elevated temperature. The difference between the flow behavior index of the UHT and the non-UHT treated beverage is likely due to the higher concentration of reactive sulfhydryl and disulfide generated by the UHT treatment [7] compared to the non-UHT treated beverage.

The data in ***Figure 3*** shows the consistency index as a function of storage time and storage temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance of the data (Table 1) showed that heat treatment, storage temperature, and storage time were the major factors influencing consistency. The storage time effect was strongly dependent on the storage temperature. The interactive effects of heat treatment-storage time, heat treatment-storage temperature and heat treatment-storage time-storage temperature were significant ($p < 0.05$). The increase in consistency of the UHT and non-UHT beverages at 40°C compared to the lower storage temperatures is likely due to structure building in the beverages enhanced by the elevated storage temperature.

One of the important attributes of whey proteins is their ability to form complexes with themselves, other proteins and pectins [11]. No difference was observed between the UHT and non-UHT beverage at 40 ^{O}C probably due to a slow rate of UHT-induced changes. Similar results have been reported for UHT whole milk [23] while other authors have found increased viscosity after UHT [24, 25].

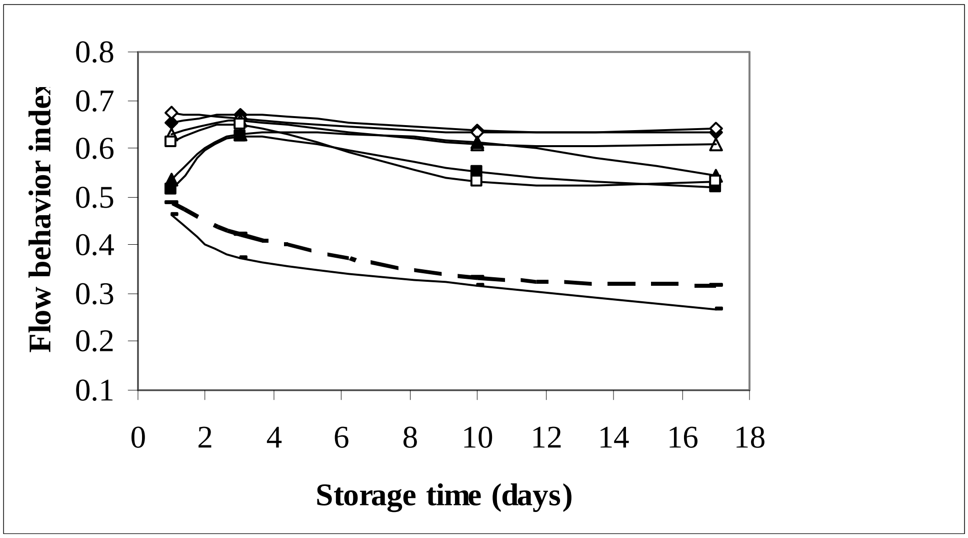

Figure 2 : *Flow behavior index of whey-banana beverages as a function of temperature and storage time.*

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at* $4^{O}C$*,*
(▲) *UHT treated whey-banana beverage stored at* $20^{O}C$*,* (Δ) *non-UHT treated whey-banana beverage stored at* $20^{O}C$
(■) *UHT treated whey-banana beverage stored at* $30^{O}C$*,* (□) *non-UHT treated whey-banana beverage stored at* $30^{O}C$*,*
(▬ ▬) *UHT treated whey-banana beverage stored at* $40^{O}C$*,* (C) *non-UHT treated whey-banana beverage stored at* $40^{O}C$*.*

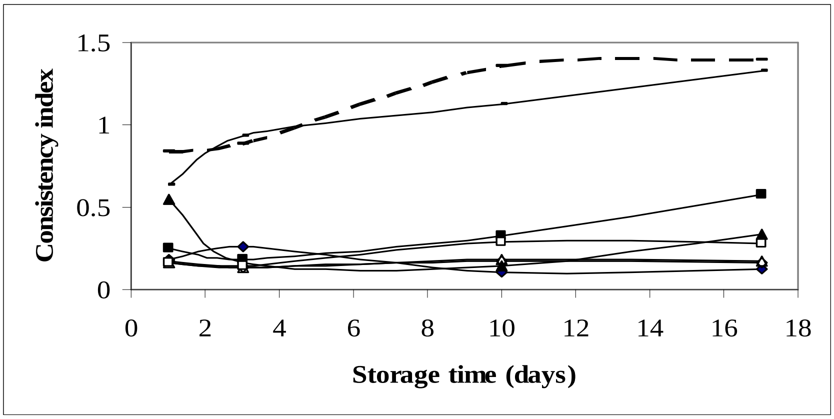

Figure 3 : *Consistency index of whey-banana beverages as a function of storage temperature and time*

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at $4^{O}C$,*
(▲) *UHT treated whey-banana beverage stored at $20^{O}C$,* (Δ) *non-UHT treated whey-banana beverage stored at $20^{O}C$*
(■) *UHT treated whey-banana beverage stored at $30^{O}C$,* (□) *non-UHT treated whey-banana beverage stored at $30^{O}C$,*
(▬ ▬) *UHT treated whey-banana beverage stored at $40^{O}C$,* (C) *non-UHT treated whey-banana beverage stored at $40^{O}C$.*

At day 1, the UHT and non-UHT beverages had comparable consistency at 4°C. However, the UHT beverages exhibited significantly ($p < 0.05$) higher consistency at 20°C, 30°C and 40°C. At day 3, the UHT beverage had significantly ($p < 0.05$) higher consistency that the non-UHT beverage at 4°C. However, the UHT and non-UHT beverage had comparable consistency at 20°C, 30°C and 40°C At day 10, the non-UHT beverage exhibited a higher consistency at 4 and 20°C while the consistency was higher ($p < 0.05$) for the UHT beverage at 40°C compared the non-UHT treated beverage. At day 17, the consistency was comparable for the UHT and non-UHT beverages stored at 4°C and 40°C whereas the consistency was higher ($p < 0.05$) for the UHT beverage at 20°C and 30°C compared to the non-UHT beverage.

III-3. Particle size

The data in ***Figure 4*** show the plot for the volume mean diameter (D_{43}) of particles as a function of storage time and temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance of the data ***(Table 1)*** showed that heat treatment and storage temperature were the major factors influencing particle mean diameter. The heat treatment effect was strongly dependent on storage temperature. There was no significant ($p > 0.05$) effect due to storage time. However, the interactive effects of storage time-storage temperature and heat treatment-storage time-storage temperature were significant. At day 1, the particle volume mean diameter was significantly higher ($p < 0.05$) for the non-UHT beverages at 4 and 30°C whereas a significantly ($p < 0.05$) higher value was observed for the UHT beverage at 40°C.

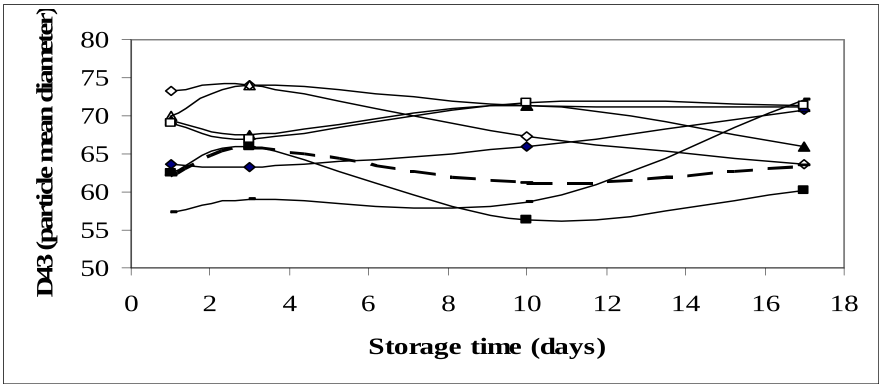

Figure 4 : *Average of volume mean diameter obtained from Malvern Mastersizer of whey-banana beverages as a function of storage temperature and time.*

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at 4°C,*
(▲) *UHT treated whey-banana beverage stored at 20°C,* (Δ) *non-UHT treated whey-banana beverage stored at 20°C*
(■) *UHT treated whey-banana beverage stored at 30°C,* (□) *non-UHT treated whey-banana beverage stored at 30°C,*
(▬ ▬) *UHT treated whey-banana beverage stored at 40°C,* (C) *non-UHT treated whey-banana beverage stored at 40°C.*

Comparable particle mean diameters were obtained at 20°C for the UHT and non-UHT beverages at day 1. At day 3, the non-UHT beverage stored at 4 and 20°C had significantly ($p < 0.05$) higher particle volume mean diameter than the UHT beverage. Significantly ($p < 0.05$) higher particle volume mean diameter was observed for the UHT beverage at 40°C compared to the non-UHT beverage. The UHT and non-UHT beverages stored at 30°C had comparable volume mean diameter of particles. At day 10, the UHT and non-UHT beverage exhibited comparable particle size at 4 and 20°C. The particle volume mean diameter was significantly ($p < 0.05$) higher for the non-UHT

beverage compared to the UHT beverage at 30°C.
However, the UHT beverage exhibited significantly ($p < 0.05$) higher particle size at 40°C. At day 17, the non-UHT beverage exhibited higher ($p < 0.05$) particle size at 20, 30 and 40°C. The changes for this variable are not as clear cut. This could be due to the complex interaction between whey proteins, pectin and polyphenols present in the whey-banana beverages. Association and dissociation reaction between β-lactoglobulin and casein and κ-casein have been reported during age gelation of UHT milk [26]. Further, denatured proteins are also susceptible to aggregation via salt bridges and hydrophobic interactions [27].

The data in ***Figure 5*** shows the plot of surface area mean diameter (D_{32}) as a function of storage time and storage temperature for both UHT and non-UHT whey-banana beverages. The analysis of variance ***(Table 1)*** showed that heat treatment was the major factor ($p < 0.001$) influencing the surface mean diameter of particles. There was no significant effect ($p > 0.05$) due to storage temperature. Storage time and storage time-storage temperature effects were significant with minor effects ($p < 0.05$ and $p < 0.01$ respectively). The interactive effects of heat treatment-storage time, heat treatment-storage temperature and heat treatment-storage time-storage temperature were not significant ($p > 0.05$).

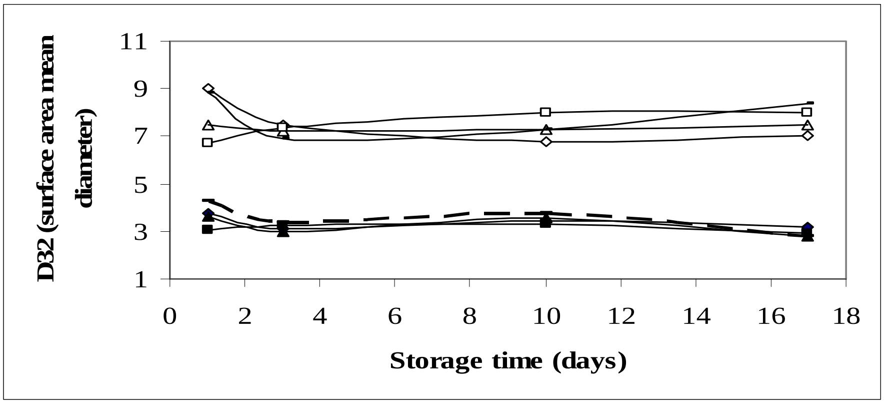

Figure 5 : *Average of surface area mean diameter of particles obtained from Malvern Mastersizer of whey-banana beverages as a Function of storage temperature and time.*

The surface area mean diameter of particles was significantly higher ($p < 0.05$) for the non-UHT than the UHT beverages at all four storage temperatures 4°C, 20°C, 30°C and 40°C for the 17 day storage period.

Further, storage time and storage temperature had no significant ($p > 0.05$) effect on the particle sizes. The smaller particle size of the UHT treated beverage could be due to the inhibitory effect of oxygen on polymerization and denaturation of β-lg. Reports indicated that oxygen acted as chain reaction break on thiol-disulfide exchange reactions during the indirect UHT process [7].

III-4. Color

The data in ***Figure 6*** show the plot for a* values versus storage time and temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance ***(Table 1)*** showed that heat treatment, storage time and storage temperature were the major factors influencing redness ($p < 0.0001$). The interactive effects of heat treatment-storage time, heat treatment-storage temperature, storage time-storage temperature, heat treatment-storage time-storage temperature were also significant ($p < 0.0001$). The UHT beverage exhibited higher redness value compared to the non-UHT beverage at all four temperatures 4°C, 20°C, 30°C and 40°C during the 10 day storage period.

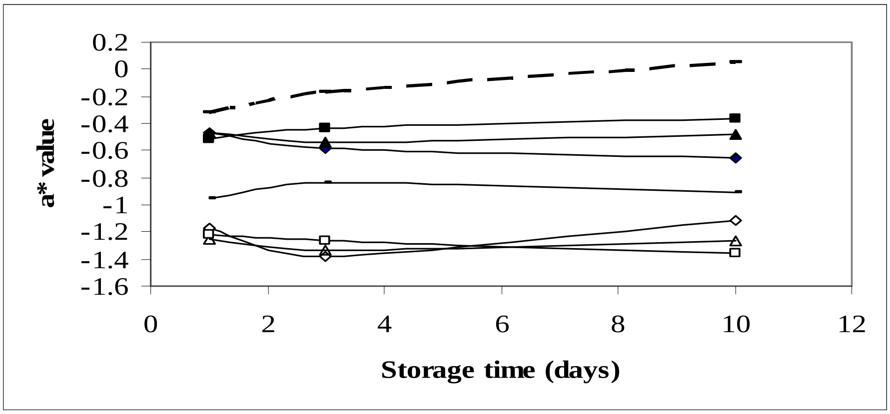

Figure 6 : *Color measurement of whey-banana beverages (a*-value) as a function of storage temperature and time.*

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at 4°C,*
(▲) *UHT treated whey-banana beverage stored at 20°C,* (Δ) *non-UHT treated whey-banana beverage stored at 20°C*
(■) *UHT treated whey-banana beverage stored at 30°C,* (□) *non-UHT treated whey-banana beverage stored at 30°C,*
(▬ ▬) *UHT treated whey-banana beverage stored at 40°C,* (C) *non-UHT treated whey-banana beverage stored at 40°C.*

The data in ***Figure 7*** show the plot of yellowness (b* values) versus storage time and temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance ***(Table 1)*** showed that heat treatment, storage temperature and storage time were the major factors influencing yellowness ($p < 0.0001$).

The interactive effects of heat treatment-storage time, heat treatment-storage temperature, storage time-storage temperature, heat treatment-storage time-storage temperature were significant ($p < 0.0001$). The UHT beverage exhibited higher yellowness value compared to the non-UHT beverage at any of the four temperatures 4°C, 20°C, 30°C and 40°C during the ten days storage period. The higher yellowness of the UHT beverages is probably due to phenolics extracted from the banana pulp by the UHT process. Better extraction of phenolics was observed from apple pulp as the temperature of juice processing increased [28].

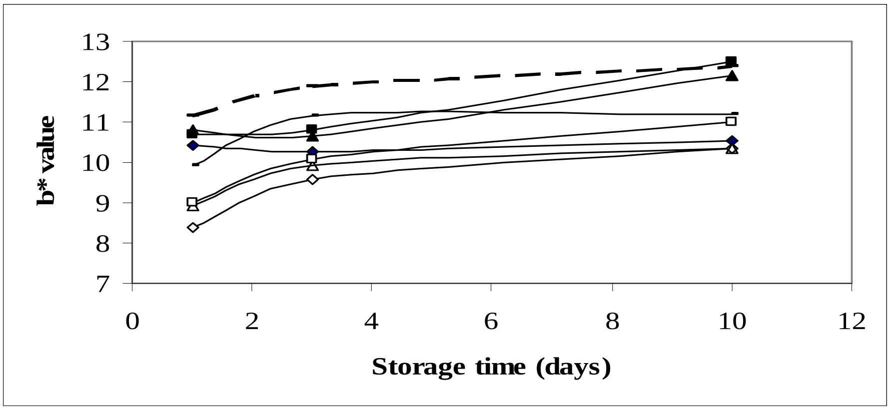

Figure 7 : *Color measurement of whey-banana beverages (b*-value) as a function of storage temperature and time.*

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at 4°C,*
(▲) *UHT treated whey-banana beverage stored at 20°C,* (Δ) *non-UHT treated whey-banana beverage stored at 20°C*
(■) *UHT treated whey-banana beverage stored at 30°C,* (☐) *non-UHT treated whey-banana beverage stored at 30°C,*
(▬ ▬) *UHT treated whey-banana beverage stored at 40°C,* (C) *non-UHT treated whey-banana beverage stored at 40°C.*

The data in ***Figure 8*** show the plot of saturation (c* value) versus storage time and storage temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance ***(Table 1)*** showed that heat treatment and storage temperature and storage time were the major factors influencing saturation ($p < 0.0001$). The interactive effects of heat treatment-storage time, heat treatment-storage temperature, storage time-storage temperature, heat treatment-storage time-storage temperature were significant ($p < 0.0001$). The UHT beverage exhibited higher saturation value compared to the non-UHT beverage at any of the four temperatures during the ten days storage period.

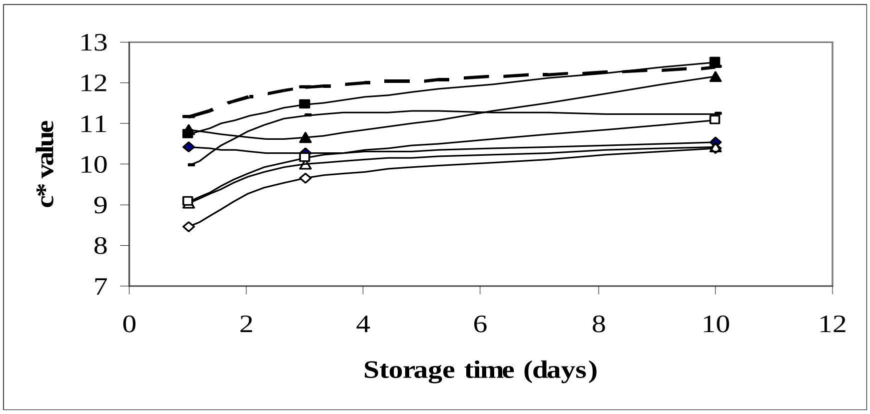

Figure 8 : *Color measurement of whey-banana beverages (c*-value) as a function of storage temperature and time.*
function of storage temperature and time.

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at 4°C,*
(▲) *UHT treated whey-banana beverage stored at 20°C,* (Δ) *non-UHT treated whey-banana beverage stored at 20°C*
(■) *UHT treated whey-banana beverage stored at 30°C,* (□) *non-UHT treated whey-banana beverage stored at 30°C,*
(▬ ▬) *UHT treated whey-banana beverage stored at 40°C,* (C) *non-UHT treated whey-banana beverage stored at 40°C.*

The results in ***Figure 9*** show the plot of hue (H* value) versus storage time and temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance ***(Table 1)*** showed that heat treatment, storage temperature and storage time were the major factors influencing hue ($p < 0.0001$). The interactive effects of these factors were significant ($p < 0.0001$). The non-UHT beverage exhibited higher hue value compared to the UHT beverage at any of the four temperatures during the ten days storage period.

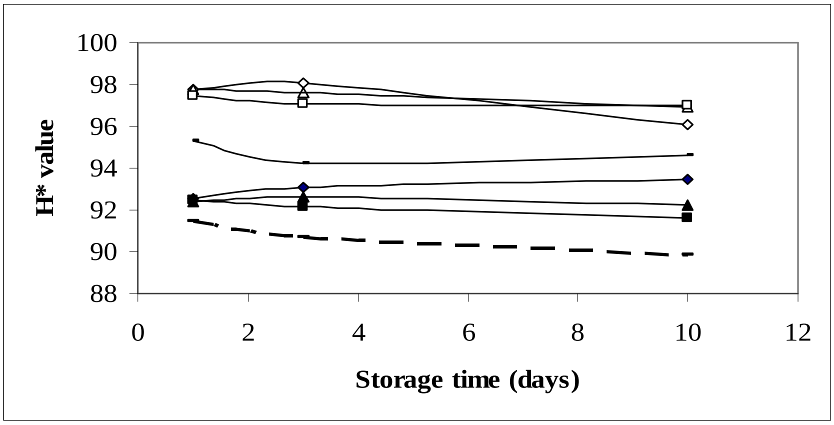

Figure 9 : *Color measurement of whey-banana beverages (H*-value) as a function of storage temperature and time.*
function of storage temperature and time.

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at 4°C,*
(▲) *UHT treated whey-banana beverage stored at 20°C,* (Δ) *non-UHT treated whey-banana beverage stored at 20°C*
(■) *UHT treated whey-banana beverage stored at 30°C,* (□) *non-UHT treated whey-banana beverage stored at 30°C,*
(▬ ▬) *UHT treated whey-banana beverage stored at 40°C,* (C) *non-UHT treated whey-banana beverage stored at 40°C.*

The data in ***Figure 10*** show the plot of whiteness (L* value) versus storage time and storage temperature for both UHT and non-UHT treated whey-banana beverages. The analysis of variance ***(Table 1)*** showed that heat treatment and storage temperature were the major factors influencing whiteness ($p < 0.0001$). Storage time effect was not significant ($p > 0.05$). The interactive effects of heat treatment-storage time, heat treatment-storage temperature, storage time-storage temperature, heat treatment-storage time-storage temperature were significant ($p < 0.01$).

Usually the UHT beverage exhibited higher whiteness value compared to the non-UHT beverage at the four temperatures during the ten days storage period. The difference in whiteness between the UHT treated sample and the untreated control is due to particle sizes. The whiter color of milk following heat treatment is due to more scattering particles produced by denaturation [29]. Browning reactions occurring in the whey-banana beverage during storage could be responsible for the color differences between the UHT and the non-UHT whey-banana beverage. The Maillard reaction was faster when the temperature was above 20°C [13]. When ketoses or aldoses are heated in presence of amines, the reducing sugars produces a glycosylamine. After rearrangement (Amadori reaction or enolization), a derivative of 1-amino-1-deoxy-D-fructose is formed in the case of glucose. This derivative at pH 5 or lower yields a 2,3-enol derivative that is converted to 3-deoxyhexosulose. After dehydration a furan derivative which corresponds to 5-hydroxymethyl-2-furaldehyde (HMF) is formed. Degradation of HMF yield organic acids and brown pigments the concentration of which increases overtime [30,31]. Thus the non-UHT whey-banana beverage containing lactose and sucrose most likely caused the changes observed in the color parameters.

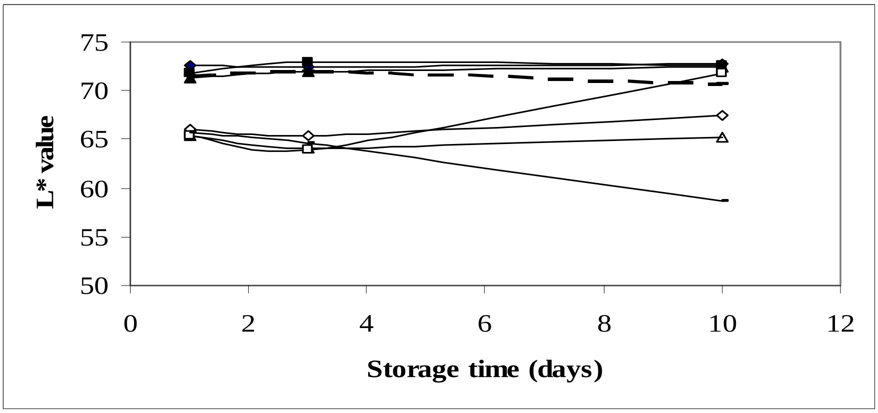

Figure 10 : *Color measurement of whey-banana beverages (L*-value) as a function of storage temperature and time.*

(◆) *UHT treated whey-banana beverage stored at 4C,* (◇) *non-UHT treated whey-banana beverage stored at 4°C,*
(▲) *UHT treated whey-banana beverage stored at 20°C,* (Δ) *non-UHT treated whey-banana beverage stored at 20°C*
(■) *UHT treated whey-banana beverage stored at 30°C,* (□) *non-UHT treated whey-banana beverage stored at 30°C,*
(▬ ▬) *UHT treated whey-banana beverage stored at 40°C,* (C) *non-UHT treated whey-banana beverage stored at 40°C.*

IV - CONCLUSION

The physical characteristics of the whey-banana beverages were affected primarily by the UHT treatment, followed by storage temperature and storage time. During storage the particle size and L* remained constant, the color values a*, b*, c*, H* increased, the flow behavior decreased with increasing temperature and the consistency increased. Reliance on indicators other than particle size to study whey-banana beverage stability could be misleading. Based mainly on its nutritive value and desirable fruity flavour, the banana beverage may be considered a potential complementary diet to support growth of malnourished populations. The mixture of the whey proteins (rich in essential amino acids) with the banana (source of carbohydrates) will greatly enhance nutrient density and quality.

Because surplus bananas are produced in developing countries, this project will likely improve the nutritional status of vulnerable populations in those areas. The failure of tropical fruit beverages on the marketplace is due to sedimentation problems arising from particle aggregation overtime. Physical changes did not affect particle size in the banana beverages likely to influence perceived quality of the beverages. Therefore, indigenous fruits such as bananas in Côte d'Ivoire can be successfully used in fortified beverages to improve their stability and most probably lower their consumer price.

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