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ENRICHING TIGER NUT MILK WITH SODIUM CASEINATE AND XANTHAN GUM IMPROVES THE PHYSICAL STABILITY AND CONSUMER ACCEPTABILITY

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ABSTRACT

Tiger nut milk (TNM) shows limited colloidal stability, which affects consumer acceptability in many parts of the world where tiger nut is cultivated. In this study, addition of proteins and hydrocolloids was used for improving the stability, and the impact on physical properties and consumer acceptance is reported. Enriching TNM by 3 g/100 g sodium caseinate and 0.1 g/100 g xanthan gum successfully impeded creaming and serum formation and resulted in a decrease of the instability index from 0.408 ± 0.023 to 0.015 ± 0.00 after applying forced sedimentation at 3000 x g for 2 h. After TNM enrichment, the viscosity of TNM increased from 3.0 ± 0.10 mPa.s to 285 ± 18 mPa.s which remained stable at elevated storage temperature. Flash profiling of TNM resulted in emerging descriptors namely *sweet, sediment, watery, raw.* Hedonic assessment by 82 consumers showed that plain TNM had the lowest rating concerning particular sensory attributes and acceptance. Enrichment resulted in more *viscous, sweet and thick* TNM products, leading to higher consumer ratings of attributes and acceptability. Thus, enriching TNM by sodium caseinates and xanthan gum is promising for improving the dispersion stability and consumer acceptance.

Contribution/Originality: This study contributes to the existing literature strategies for improving tiger nut milk stability and consumer acceptance. We show that by enrichning with sodium caseinate and xanthan gum, more viscous, sweet, thick and physically stable tiger nut milk products with higher consumer ratings of attributes and acceptability can be achieved.

1. INTRODUCTION

Tiger nut milk (TNM) is an off-white dispersion that is obtained through aqueous extraction of crushed tiger nuts (*Cyperus esculentus* L). The process for preparing the naturally sweet TNM involves washing of tiger nuts and soaking to soften the tissues, and wet-milling and subsequent filter-pressing of the resulting mush to separate the aqueous extract from the residue (Belewu, 2007; Coşkuner, Ercan, Karababa, & Nazlıcan, 2002; Kizzie-Hayford, Jaros, Schneider, & Rohm, 2015). Depending on the extraction parameters employed, TNM dry matter basis may comprise 8.6 g/100 g protein, 36.3 g/100 g fat, 2.9 g/100 g minerals, 3.2 g/100 g soluble fibre, 5.2 g/100 g

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insolube fibre, and 43.8 g/100 g carbohydrates (Kizzie-Hayford et al. 2015) showing that TNM represents a valuable source of nutrients. However, the natural dispersion is unstable and undergoes rapid creaming by forming an oil-rich top layer and a clear lower layer over a short (1-16 h) storage period (Kizzie-Hayford et al., 2015). Formation of starch granules at the buttom layer of TNM was previuosly reported (Codina-Torrella, Guamis, Ferragut, & Trujillo, 2017; Djomdi et al., 2020). This instability and the sub-optimal flow properties of TNM are known to adversely affect consumer acceptance of TNM and related products (Dhankhar & Kundu, 2021; Kizzie-Hayford et al., 2021; Kizzie-Hayford, Jaros, Zahn, & Rohm, 2016; Sanful, 2009) which therefore need improvement.

On the one hand, Codina-Torrella et al. (2017) showed that ultra high pressure homogenisation (UHP) improved stability and physicochemical properties of TNM, which is still relevant for TNM processing. On the other hand, the application of UHP either for domestic or commercial purposes represents a major capital investment hurdle for several micro, small or medium scale tiger nut milk-related start up enterprises, espcially in many parts of low income countries where TNM is still explored for being integrated into the food chain. We propose that enriching TNM by proteins and hydrocolloids could alternatively serve as pragmatic approach for enhancing TNM stability and sensory properties, and hence, consumer acceptance.

In dairy systems, casein is known to adsorb at the water-oil interface, forming a steric-stabilizing layer and functionally contributing to the stability of the dispersion (Dickinson, Golding, & Povey, 1997). Additionally, soy protein is reported to show emulsifying and gelling properties, and may be important for mitigating phase separation in instable dispersions (Kinsella, 1979). Bouyer, Mekhloufi, Huang, Rosilio, and Agnely (2013) and Cao, Dickinson, and Wedlock (1990) showed that enriching instable oil-in-water emulsion by high molecular weight polysacharides such as guar gum, carboxymethyl cellulose or xanthan gum effectively reduced creaming, flocculation and coalescence by influencing the rheological behaviour of the continuous phase. To enhance processing of tiger nut milk into more stable dispersions and acceptable beverages, surfactants or texture modifiers may hold promise. However, until now, effects of textural modifications of TNM on the physical stability and consumer acceptance is not known .

In this study, several texture modifiers are investigated for enhancing TNM and the impact on the physical stability, sensory attributes and consumer acceptance of enriched TNM are presented.

2. MATERIALS AND METHODS

2.1. Sample Collection and Preparation

A batch of freshly harvested tiger nuts (brown variety) was obtained from farmers in Twifo Praso (DMS: 5° 36 ' 59.99 " N - 1° 32 ' 59.99 " W), Central Region, Ghana. Tiger nuts were rubbed together in a basket to separate sand and root hairs followed by washing with tap water and drying in wooden trays under shade at ambient temperature (26 °C - 32 °C) for one month. Darkened or broken tiger nuts were excluded and the bulk of the nuts was packed and stored in a refrigerator (5 - 6 °C) until use.

Sodium-caseinate, Cn (Sigma-Aldrich Chemie GmbH, Steinheim, Germany), soy protein isolate, SPI (Nutrition Factory Alphacaps GmbH, Augustdorf, Germany), average-viscosity sodium carboxymethylcellulose, CMC (Fluka Bio Chemika, Buchs, China), guar gum, G (Sigma, Steinheim, Germany) und xanthan gum, X (Cargill, Saint-Germain-en-Laye, France) were used in the study.

2.2. Preparation of Tiger Nut Milk

Tiger nut milk (TNM) was prepared from tiger nuts by adopting a previously reported procedure (Kizzie-Hayford et al., 2015) with few modifications: after soaking in distilled water at 60 °C for 6 h to soften the tissue, tiger nuts were disinfected by steeping in 0.05% sodium hypochlorite (NaOCl) for 30 min and washed five times in distilled water to remove residual disinfectant, root hairs and sand. Then, the sample was wet-comminuted using a Kult pro mixer for 3 min. After filter-pressing of the resulting mush, the obtained TNM was concentrated to 30

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g/100 g dry matter (DM) by heating to 70 °C using an R-124 rotational evaporator joined to a B-172 vacuum controller (BÜCHI Labortechnik AG, Flawil, Switzerland) for 1 h. A reference sample was prepared by diluting TNM with distilled water to achieve approx. 10 g/100 g DM.

2.3. Preparation of Enriched Tiger Nut Milk

Dispersions of soy protein isolate, sodium caseinate, guar gum, sodium carboxymethyl cellulose or xanthan gum were prepared by adding the appropriate amount to distilled water and subsequent mixing on a magnetic stirrer at 25 °C for 2 h. Proteins and hydrocolloids were added to TNM and homogenized using a T20 Ultra Turrax homogenizer (IKA GmbH & CO. KG, Staufen, Germany) at 11,000 rpm for 3 min to obtain dispersions with a composition as outlined in Table 1. To prevent microbiological growth during storage, 0.03 g/kg sodium azide was added but excluded from TNM samples used for sensory analysis. After transferring 18 g samples into glass tubes (height, 150 mm; outer diameter, 1.6 mm; internal diameter, 1.4 mm) and plugging with a silicone stopper, dispersions were stored in an environmental chamber at 20 °C for 7 d for stability measurements.

2.4. Gravitational Stability of Enriched Tiger Nut Milk

During storage, TNM mixtures were visually assessed for emulsion breakdown by measuring the height of an upper cream layer or a clear serum layer (Wu et al., 2011). Using a calliper, the creaming stability (Creaming index, Ci or Serum index, Si) of the mixture was determined using Equation 1 and Equation 2 by measuring the height of the cream layer (H_C) or the serum layer (H_S), respectively, during storage and expressing it as a fraction of the total height of the dispersion (H_T) according to Wu et al. (2011) (14):

$$Ci = 100 \cdot \frac{Hc}{H_T} \quad (1)$$

$$Si = 100 \cdot \frac{H_S}{H_T} \quad (2)$$

2.5. Accelerated Gravitational Stability of Enriched Tiger Nut Milk

Based on the results of the gravitational stability measurements of enriched tiger nut milk, three stable dispersions (dispersions with creaming index, Ci ≤ 5 % or Serum index, Si ≤ 5 %) were chosen for further analysis. Thus, the selected samples comprised approx. 10 g tiger nut solids (TNM, reference sample) or 10 g tiger nut solids enriched with 0.1 g xanthan gum and 1.0 g sodium caseinate (1CnX) or 3.0 g sodium caseinate (3CnX) per 100 g sample, and 10.0 g/100 g tiger nut solids, 0.3 g guar gum and 2.0 g/100 g sodium caseinate (2CnG) per 100 g.

The effect of temperature on the stability of selected TNM mixtures was studied using a LUMiSizer (L.U.M., GmbH, Berlin, Germany); a multi-sample analytical centrifuge that enables measurement of the relative intensity of infra-red light transmitted as a function of time and position over the sample length, and which provides data on the kinetics of the separation process (Lerche & Sobisch, 2007).

Prior to stability measurements, samples were transferred to a refrigerator to mimic either cold storage (6 °C, 24 h), a temperature-controlled chamber for warm storage (45 °C, 3 h) or a water bath for pasteurization conditions (70 °C, 15 min). After equilibration at 20 °C, 2 mL TNM mixture was transferred into sample tubes and centrifuged at 2,300 x g for 7.5 h at 20 °C. Transmission profiles were set at 5 s intervals for 10 min and thereafter, 30 s for 7.5 h. Instability index (-) from transmission profiles were determined using the SEPView software. Results on instability indices are based on arithmetic average of duplicate determinations.

2.6. Viscosity of Enriched Tiger Nut Milk

Apparent viscosity of TNM mixtures was measured by using a Physica MCR 301 rheometer (Anton Paar GmbH, Graz, Austria) equipped with a cylindrical geometry (inner diameter, 24.66 mm; outer diameter, 26.66 mm;

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height, 40 mm). After the thermal treatments, TNM mixtures were equilibrated at 20 °C for 5 min and a shear rate sweep from 0.01/s to 100/s was applied. The Herschel-Bulkley-Model was used to determine the rheological properties of enriched TNM according to Equation 3.

$$\tau = \tau_0 + K \cdot \dot{\gamma}^n \quad (3)$$

where τ (Pa) is shear stress, τ_o (Pa) is the yield stress, K ($mPa.s^n$) is the consistency index, $\dot{\gamma}$(1/s) is shear rate, and n (-) is the flow index. Duplicate determinations were done.

2.7. Sensory Analysis of Enriched Tiger Nut Milk

Attributes of plain and enriched TNM were determined using flash profiling by adopting a previously described procedure (Kizzie-Hayford et al., 2016). A panel of 10 members (males, 5; females, 5; average age, 22 y) was recruited for the study. Samples presented for sensory assessment were plain tiger nut milk (TNM) and TNM enriched with 0.1 g/100 g xanthan gum and 1 g/100 g or 3 g/100 g sodium caseinate (1CnX or 3CnX), respectively, and 0.3 g/100 g guar gum and 2 g/100 g sodium caseinate (2CnG). An identical sample from 1CnX was included to assess the discriminatory quality. Samples were encoded with 3-digit random codes and simultaneously served in counterbalanced order in 30 mL transparent cups.

Additionally, consumer preference of enriched TNM was determined using a 9-point hedonic scale as described by Lawless and Heymann (2010). For this, product attributes (aroma, thickness, consistency, mouth feel, aftertaste and acceptance) were rated from 1 (dislike extremely) to 9 (like extremely). A panel of 82 members (males, 45; females, 37; mean age, 24 y) were randomly recruited for the study. Plain tiger nut milk (TNM, control sample) and enriched TNM, namely, 1CnX, 2CnG and 3CnX were presented for evaluation. A single experiment for hedonic evaluation and duplicate experiments for flash profiling were conducted.

2.8. Statistical Analysis

Data were evaluated using one-way analysis of variance (ANOVA). Tukey HSD or Games-Howell post hoc analysis was used to compare the mean values for significance ($P < 0.05$) using SPSS software package version 16.0 (SPSS Inc., Chicago, IL, USA). Raw data on the sensory attributes and the corresponding intensities from flash profiling were analyzed using principal component and generalized procrustees analyses using the Senstools.Net software (OP&P Product Research BV, Utrecht, Netherlands). All significance statements refer to $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1. Effects of Enrichment on Tiger Nut Milk Stability

Plain TNM shows emulsion failure evidenced by the formation of a creamy phase and/or a solids-depleted serum phase (Codina-Torrella et al., 2017; Kizzie-Hayford et al., 2015). The effects of enriching TNM with proteins and/or hydrocolloids on creamy phase formation is shown in Table 1. Plain TNM showed a creamy index of 5.38 % after 7 d storage. This could be partly caused by the coalescence of TNM lipids (Kizzie-Hayford et al., 2015). Enriching TNM in protein and hydrocolloids effectively impeded creaming, which can be ascribed to the viscosity-enhancing and/or the emulsifying effects of the polymers on the continuous phase or on the TNM droplets, respectively (Dickinson et al., 1997).

The addition of only proteins to TNM was not effective to mitigate creaming, probably because proteins show lower viscosifying effects than their mixtures with the hydrocolloids. Furthermore, proteins are known to show a low rate of unfolding and diffusion, causing a lower rate of alignment at oil-water interfaces compared to the rate of TNM emulsion breakdown (Lam & Nickerson, 2013). Increasing the of sodium caseinate concentration in TNM resulted in a higher creamy phase formation, probably due to depletion flocculation, in which casein molecules are known to contribute to high osmotic differences in the bulk mixture, leading to droplet aggregation and phase separation (Dickinson et al., 1997).

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Table-1. Separation of a creamy phase (%) and the serum phase (%) of enriched tiger nut milk stored at 20 °C for 7 d. Creamy phase and serum phase of plain tiger nut milk (9.58 ± 0.12 g/100 g, reference sample) were 5.38 % and 69.9 %, respectively.

Hydrocolloids (g/100 g)		Soy protein isolate (g/100g)		Sodium caseinate (g/100 g)			Soy protein isolate (g/100g)		Sodium caseinate (g/100 g)		
		Creamy phase					Serum phase				
		+1.00	+2.00	+1.00	+2.00	+3.00	+1.00	+2.00	+1.00	+2.00	+3.00
	+0.0	4.70	3.77	19.20	26.76	37.78	6.27	10.07	3.06	3.67	3.61
CMC	+0.20	0.00	0.00	0.00	0.00	0.00	57.30	36.16	67.27	53.98	27.27
	+0.40	0.00	0.00	0.00	0.00	0.00	39.69	21.38	37.27	22.12	16.31
Guar gum	+0.15	0.00	0.00	0.00	0.00	0.00	30.96	28.78	62.47	32.55	19.59
	+0.30	0.00	0.00	0.00	0.00	0.00	50.79	21.68	8.47	1.79	5.75
Xanthan gum	+0.05	0.00	3.86	0.00	0.00	2.94	57.90	46.86	33.67	8.53	6.49
	+0.10	0.00	0.00	0.00	3.48	0.00	5.58	13.00	0.00	0.00	0.00

Note: **CMC:** Sodium carboxymethyl cellulose. Highlighted letters refer to values for the selection of the more stable TNM mixtures. Bold letters refer to concentrations of proteins or hydrocolloids.

The impact of adding proteins and hydrocolloids to TNM on serum phase formation in Table 1 depicts that plain TNM underwent high emulsion breakdown by forming a serum index of 69.9 %, showing a more severe phenomenon than creamy phase formation. Serum formation is known to be caused by the aggregation of TNM polymers such as proteins, lipids and carbohydrates (Kizzie-Hayford et al., 2015) leading to the separation from the bulk liquid phase (Doublier, C., Renard, & Sanchez, 2000). Enrichment of TNM by only sodium caseinate, which has a lower molecular mass, higher molecular flexibility and a more open structure (Lesmes, Baudot, & McClements, 2010) than that of soy protein isolates (Chen et al., 2014) appeared to be more effective in reducing serum formation.

Enriching TNM with hydrocolloids at low concentration resulted in higher serum phase formation than that of systems without hydrocolloids or with sufficiently high hydrocolloid concentration. According to McClements (2000) this phenomenon is usually promoted by the induction of droplet flocculation, which is triggered by the adsorption of hydrocolloids at particle surfaces leading to bridging flocculation phenomena of hydrocolloids. Enrichment of TNM with sodium caseinate and xanthan (0.1 g/100 g) or with guar gum (0.30 g/100 g) led to more stable dispersions than containing carboxymethyl cellulose. Xanthan gum is known to exhibit a lower critical viscosity concentration, higher low-shear viscosity and critical flocculation concentration than carboxymethyl cellulose, which could contribute to the observed differences in their emulsion-stabilizing properties (Holzwarth, 1978; McClements, 2000). The results show that enriching TNM with sodium caseinate and 0.1 g/100 g xanthan or 0.30 g/100 g guar gum could be important for generating dispersions with enhanced stability.

3.2. Effects of Temperature on Stability of Enriched Tiger Nut Milk

The impact of temperature on the stability of enriched TNM was monitored under accelerated gravitation and the instability index (I) of the dispersions, from I equals 0 (stable) to 1.0 (instable), was used as a measure of stability. In Figure 1, the instability index of plain TNM at 6 °C under centrifugation for 2 h was 0.41 ± 0.02. After enriching with proteins and hydrocolloids, 3CnX mixture showed the highest stability with I = 0.09 ± 0.01, followed by 1CnX (I = 0.14 ± 0.01) and 2CnG (I = 0.23 ± 0.03).

Treatment of enriched TNM at 45 °C revealed a remarkable decrease in the stability of 2CnG (0.62 ± 0.05) whereas those of 1 CnX (0.97 ± 0.01) or 3 CnX (0.10 ±0.01) showed no significant differences. Rao, Walter, and Cooley (1981) showed that, at elevated temperature, some galactose moieties detach from the main mannose chain of guar gum at a faster rate, which could contribute to the loss of branching and diminished steric stabilisation. Treatment of enriched TNM at 70 °C for 15 min resulted in some decrease in stability of 1CnX (0.29 ± 0.01) and 3CnX (0.26 ± 0.01). Paoletti, Cesàro, and Delben (1983) observed that xanthan gum undergoes reversible transformation from a helix structure to a more disordered single-stranded chains when subjected to prolonged

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heating, which could contribute to the destabilization process. The results show that enriching TNM with xanthan gum leads to a more thermo-stable dispersion than that of guar gum.

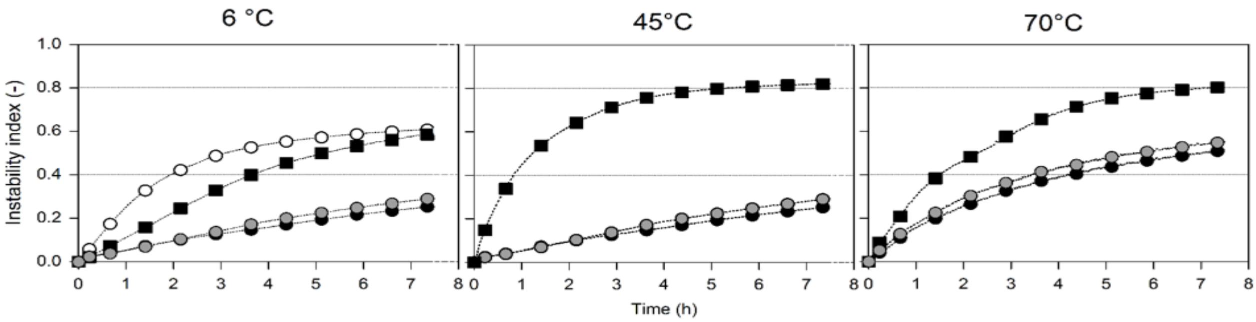

Figure-1. Effect of temperature on the instability index of tiger nut milk enriched with protein and hydrocolloids. Open circles, 9.58 ± 0.12 g/100 g tiger nut milk; grey and dark circles, 9.58 ± 0.12 g/100 g tiger nut solids enriched with 0.1 g xanthan and 1.0 g or 3.0 g sodium caseinate (1CnX or 3CnX) per 100 g sample, respectively; dark squares, 9.58 ± 0.12 g/100 g tiger nut enriched with 0.3 g guar gum and 2.0 g sodium caseinate (2CnG) per 100 g sample. Each curve represents the arithmetic mean of duplicate measurements. Measurement of instability index was continuous, only selected data points are displayed.

3.3. Viscosity and Flow Properties of Enriched Tiger Nut Milk

Plain tiger nut milk comprising 9.58 ± 0.12 g /100 g tiger nut solids at 6 °C revealed almost Newtonian behaviour with a viscosity of 3.00 ± 0.10 mPa.s at a shear rate of 1.0/s Figure 2.

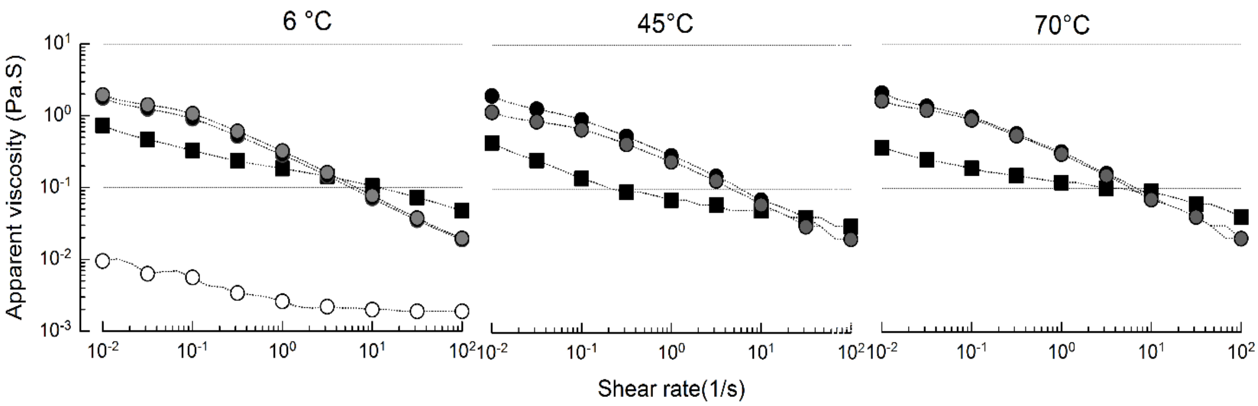

Figure-2. Effect of temperature on apparent viscosity of tiger nut milk. Open circles, 9.58 ± 0.12 g/100 g tiger nut milk; grey and dark circles, 9.58 ± 0.12 g/100 g tiger nut solids enriched with 0.1 g xanthan and 1.0 g or 3.0 g sodium caseinate (1 CnX or 3 CnX) per 100 g sample, respectively; dark squares, 9.58 ± 0.12 g/100 g tiger nut enriched with 0.3 g guar gum and 2.0 g sodium caseinate (2 CnG) per 100 g sample. Each curve represents the arithmetic mean of duplicate measurements. Measurement of viscosity was continuous, only selected data points are displayed.

Addition of the proteins and hydrocolloids to TNM increased the viscosity to 184 ± 11.0 mPa.s (2CnG), 245 ± 1.0 mPa.s (1CnX) and 285 ± 18 mPa.s (3CnX) at comparable shear rate, and led to a shear-thinning behaviour (Table 2). The order of viscosity was reflected in the increasing order of accelerated gravitational stability and corroborates the contribution of viscosity to colloidal stability (Tadros, 2013).

Table-2. Rheological characteristics of enriched tiger nut milk beverage.

Samples[1]	Flow index, n (-)	Consistency, K (Pa.s^n)
TNM	1.013±0.001^a	0.002±0.000^a
1CnX	0.488±0.031^b	0.335±0.088^b
2CnG	0.770±0.015^c	0.181±0.009^c
3CnX	0.434±0.006^b	0.289±0.017^b

Note: [1] TNM, 9.58 ± 0.12 g/100 g tiger nut milk; 1CnX or 3CnX, 9.58 ± 0.12 g/100 g tiger nut solids enriched in 0.1 g xanthan and 1.0 g or 3.0 g sodium caseinate per 100 g sample, respectively; 2CnG, 9.58 ± 0.12 g/100 g tiger nut enriched in 0.3 g guar gum and 2.0 g sodium caseinate per 100 g sample. Values represent the arithmetic mean of triplicate determinations.

An increase in treatment temperature to 45 °C or 70 °C did not significantly affect viscosity of systems enriched with xanthan, but decreased that of 2CnG to 71.0 ± 3.0 mPa.s, which could partly contribute to the

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decline in the colloidal stability. The results indicate that enriching TNM with xanthan gum leads to dispersions with higher resistance to changes in viscosity than guar gum at high temperature treatments.

3.4. Sensory Properties of Enriched Tiger Nut Milk

Principal component analysis of the consensus space and the resulting product configuration map in Figure 3 shows the impact of enriching TNM with proteins and hydrocolloids on clustering of the resulting TNM products. Dimension 1 and Dimension 2 accounted for a real variance of 79.51 % and dimension 3 contributed by 6.45 %.

The coordinates of the two related samples presented to panelists and that of the replicates clustered together, showing that the assessment was reliably discriminative (Díaz-Maroto, González Viñas, & Cabezudo, 2002).

In total, the panelists generated 18 different descriptors which is lower than those reported for fermented TNM (Kizzie-Hayford et al., 2016). More frequently used descriptors for TNM were *sediment, sweet, watery* and *raw.*

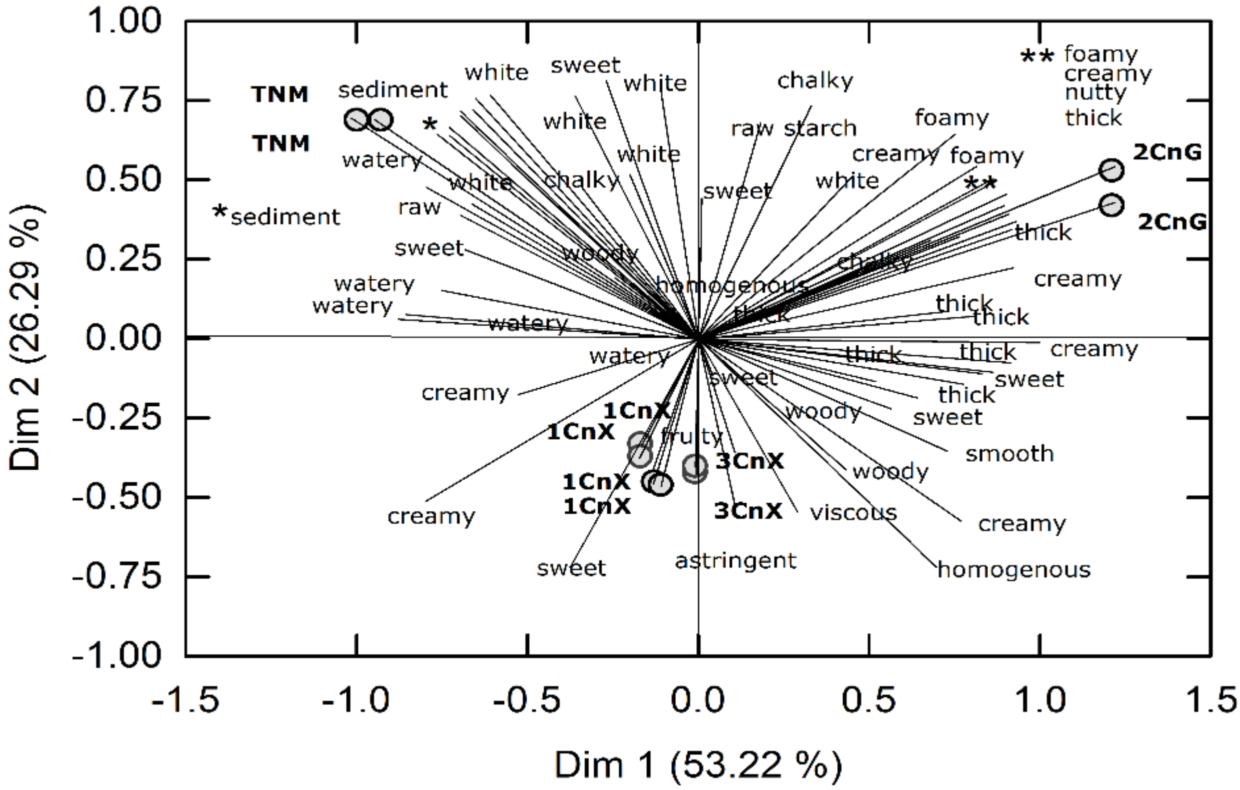

Figure-3. GPA group average plots for descriptors of tiger nut milk (9.58 ± 0.12 g/100 g, TNM) enriched with 1 g/100 g sodium caseinate and 0.2 g/100 g xanthan gum (1CnX), 2 g/100 g sodium caseinate and 0.2 g/100 g guar gum (2CnG) or 3 g/100 g sodium caseinate and 0.2 g/100 g xanthan gum (3CnX). Plots are based on duplicate experiments.

Enrichment of TNM impacted the attributes of TNM. Here, similarly emerging descriptors for 1CnX and 3CnX were identified, and were *viscous, sweet and thick*. Descriptors for 2CnG were *foamy, creamy, thick and nutty*, showing that enriching TNM with casein and xanthan gum or guar gum generates products of variable attributes, which can be useful for modifying the sensory properties of TNM.

Figure 4 shows the impact of enriching TNM with proteins and hydrocolloids on the sensory appeal of TNM. One the one hand, the results depict that TNM enrichment did not affect consumers appeal for TNM aroma. On the other hand, 3CnX showed the highest consumer rating followed by a comparable rating for 1CnX and 2CnG in terms of thickness, consistency, mouthfeel, aftertaste and acceptance.

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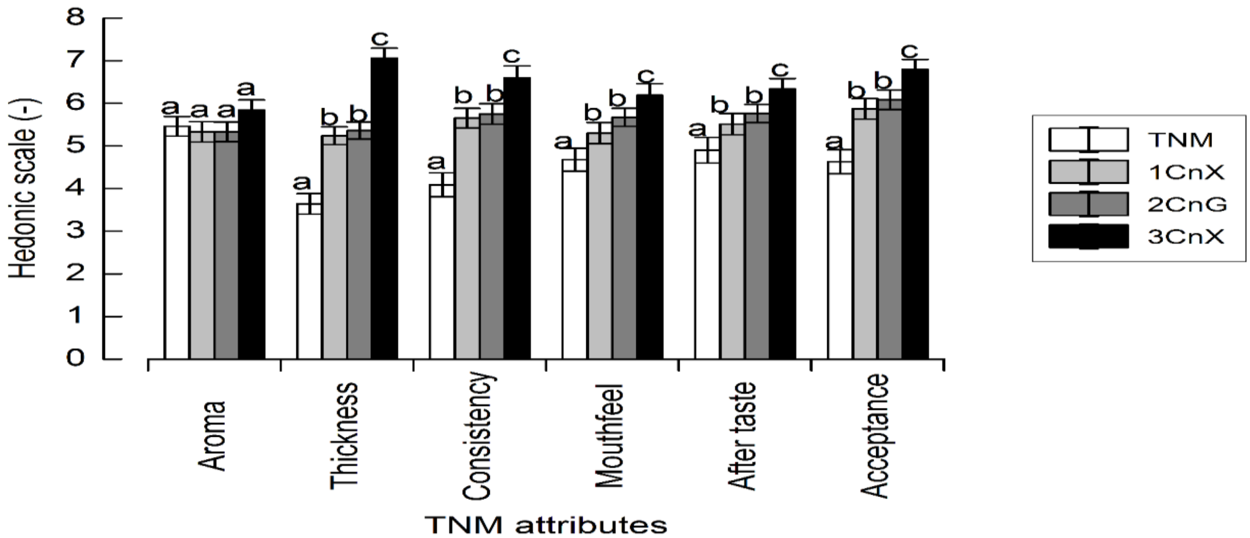

Figure-4. Sensory scores for tiger nut milk (9.58 ± 0.12 g /100 g, TNM) enriched with 1 g/100 g sodium caseinate and 0.2 g/100 g xanthan gum (1CnX), 2 g/100 g sodium caseinate and 0.2 g/100 g guar gum (2CnG) or 3 g/100 g sodium caseinate and 0.2 g/100 g xanthan gum (3CnX). Scale from 1 (dislike extremely) to 9 (like extremely). Bars with different letters in the same category of attributes are significantly different at $p < 0.05$.

Plain TNM showed the lowest score for the indicated attributes, which is probably contributed by the characteristic *raw feel*, *sedimentation* and *watery* attributes. The results show that enriching TNM with sodium caseinate and xanthan or guar gum could be relevant for enhancing consumer acceptability by improving the thickness, consistency, mouthfeel and aftertaste.

4. CONCLUSIONS

Tiger nut milk showed emulsion breakdown by forming a creamy phase and a clear serum phase. Tiger nut milk enriched with sodium caseinate and xanthan gum was more effective for improving the physical stability, especially by generating systems with a more temperature-stable viscosity than TNM systems enriched with guar gum. The addition of sodium caseinate and xanthan gum holds great potential for enhancing the nutritional quality of TNM. Descriptors used for plain TNM were *sweet*, *watery*, *sediment* and *raw* but received the lowest consumer rating. In contrast, descriptors used after enriching TNM with sodium caseinate and xanthan gum were *viscous*, *sweet and thick*. Enrichment with 3 g/100 g sodium caseinate and 0.1 g/100 g xanthan gum (3 CnX) received the highest consumer rating for all attributes, and thus, recommended for improving the physical stability, nutritional quality and consumer acceptability of TNM.

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REFERENCES

Belewu, Y. (2007). Comparative physico-chemical evaluation of tiger nut, soybean and coconut milk sources. *International Journal of Agriculture & Biology*, *9*(5), 785–787.

Bouyer, E., Mekhloufi, G., Huang, N., Rosilio, V., & Agnely, F. (2013). β-lactoglobulin, gum arabic, and xanthan gum for emulsifying sweet almond oil: formulation and stabilization mechanisms of pharmaceutical emulsions. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *433*, 77–87. Available at: https://doi.org/10.1016/j.colsurfa.2013.04.065.

Cao, Y., Dickinson, E., & Wedlock, D. J. (1990). Creaming and flocculation in emulsions containing polysaccharide. *Food Hydrocolloids*, *4*(3), 185–195. Available at: https://doi.org/10.1016/S0268-005X(09)80151-3.

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Chen, W., Li X, M., Rahman, T. R., Mohammed, A. H. N., Dey, K., & Mohammed, S. R. (2014). Emulsification properties of soy bean protein. *Nusantara Bioscience, 6*(2), 196–202. Available at: https://doi.org/10.13057/nusbiosci/n060213.

Codina-Torrella, I., Guamis, B., Ferragut, V., & Trujillo, A. (2017). Potential application of ultra-high pressure homogenization in the physico-chemical stabilization of tiger nuts' milk beverage. *Innovative Food Science & Emerging Technologies, 40*, 42-51. Available at: https://doi.org/10.1016/j.ifset.2016.06.023.

Coşkuner, Y., Ercan, R., Karababa, E., & Nazlıcan, A. N. (2002). Physical and chemical properties of chufa (Cyperus esculentus L) tubers grown in the Çukurova region of Turkey. *Journal of the Science of Food and Agriculture, 82*(6), 625-631. Available at: https://doi.org/10.1002/jsfa.1091.

Dhankhar, J., & Kundu, P. (2021). Stability aspects of non-dairy milk alternatives'. In Milk Substitutes - Selected Aspects, edited by Małgorzata Ziarno (pp. 35-50). London, Uited Kingdom: Intech Open.

Díaz-Maroto, M. C., González Viñas, M. A., & Cabezudo, M. D. (2002). Evaluation of the effect of drying on aroma of parsley by free choice profiling. *European Food Research and Technology, 216*(3), 227–232. Available at: https://doi.org/10.1007/s00217-002-0643-6.

Dickinson, E., Golding, M., & Povey, M. J. W. (1997). Creaming and flocculation of oil-in-water emulsions containing sodium caseinate. *Journal of Colloid and Interface Science, 185*(2), 515–529. Available at: https://doi.org/10.1006/jcis.1996.4605.

Djomdi, B. H., Olivier, G., Thierry, T., D., C., P., G., Ejoh, R., & Ndjouenkeu, R. (2020). Innovation in tiger nut (Cyperus esculentus L) milk production: In situ hydrolysis of starch. *Polymers, 12* (6), 1404. Available at: https://doi.org/10.3390/polym12061404.

Doublier, J.-L., C., G., Renard, D., & Sanchez, C. (2000). Protein–polysaccharide interactions. *Current Opinion in Colloid & Interface Science, 5*(3–4), 202–214. Available at: https://doi.org/10.1016/S1359-0294(00)00054-6.

Holzwarth, G. (1978). Molecular weight of xanthan polysaccharide. *Carbohydrate Research, 66*(1), 173–186. Available at: https://doi.org/10.1016/S0008-6215(00)83250-4.

Kinsella, J. E. (1979). Functional properties of soy proteins. *Journal of the American Oil Chemists Society, 56*(3), 242–258. Available at: https://doi.org/10.1007/BF02671468.

Kizzie-Hayford, N., Dabie, K., Kyei-Asante, B., Ampofo-Asiama, J., Zahn, S., Jaros, D., & Rohm, H. (2021). Storage temperature of tiger nuts (Cyperus esculentus L) affects enzyme activity, proximate composition and properties of lactic acid fermented tiger nut milk derived thereof. *LWT, 137*, 110417. Available at: https://doi.org/10.1016/j.lwt.2020.110417.

Kizzie-Hayford, N., Jaros, D., Zahn, S., & Rohm, H. (2016). Effects of protein enrichment on the microbiological, physicochemical and sensory properties of fermented tiger nut milk. *LWT, 74*, 319-324. Available at: https://doi.org/10.1016/j.lwt.2016.07.067.

Kizzie-Hayford, N., Jaros, D., Schneider, Y., & Rohm, H. (2015). Characteristics of tiger nut milk: Effects of milling. *International Journal of Food Science & Technology, 20*(2), 381–388. Available at: https://doi.org/10.1111/ijfs.12649.

Lam, R. S. H., & Nickerson, M. T. (2013). Food proteins: A review on their emulsifying properties using a structure–function approach. *Food Chemistry, 141*(2), 975–984. Available at: https://doi.org/10.1016/j.foodchem.2013.04.038.

Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: Principles and practices* (Vol. 2). New York: Springer.

Lerche, D., & Sobisch, T. (2007). Consolidation of concentrated dispersions of nano-and microparticles determined by analytical centrifugation. *Powder Technology, 174*(1-2), 46-49. Available at: https://doi.org/10.1016/j.powtec.2006.10.020.

Lesmes, U., Baudot, P., & McClements, D. J. (2010). Impact of interfacial composition on physical stability and in vitro lipase digestibility of triacylglycerol oil droplets coated with lactoferrin and/or caseinate. *Journal of Agricultural and Food Chemistry, 58*(13), 7962-7969. Available at: https://doi.org/10.1021/jf100703c.

McClements, D. (2000). Comments on viscosity enhancement and depletion flocculation by polysaccharides. *Food Hydrocolloids, 14*(2), 173-177. Available at: https://doi.org/10.1016/s0268-005x(99)00065-x.

Paoletti, S., Cesàro, A., & Delben, F. (1983). Thermally induced conformational transition of xanthan polyelectrolyte. *Carbohydrate Research, 123*(1), 173-178. Available at: https://doi.org/10.1016/0008-6215(83)88394-3.

© 2021 Conscientia Beam. All Rights Reserved.

Rao, M. A., Walter, R. H., & Cooley, H. J. (1981). Effect of heat treatment on the flow properties of aqueous guar gum and sodium carboxymethylcellulose (CMC) solutions. *Journal of Food Science*, *46*(3), 896–899. Available at: https://doi.org/10.1111/j.1365-2621.1981.tb15374.x.

Sanful, R. E. (2009). Production and sensory evaluation of tigernut beverages. *Pakistan Journal of Nutrition*, *8*(5), 688-690. Available at: https://doi.org/10.3923/pjn.2009.688.690.

Tadros, T. F. (2013). *Emulsion formation and stability. Topics in colloid and interface science*. Weinheim: Wiley-VCH.

Wu, N.-N., Yang, X.-Q., Teng, Z., Yin, S.-W., Zhu, J.-H., & Qi, J.-R. (2011). Stabilization of soybean oil body emulsions using κ, ι, λ-carrageenan at different pH values. *Food Research International*, *44*(4), 1059-1068. Available at: https://doi.org/10.1016/j.foodres.2011.03.019.

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