

Kinetics of Enzyme-Assisted Extraction of Tigernut Milks (*Cyperus esculentus* L.) Using Mixture of Pectinases, Hemicellulases and β -Glucanases

Audray Vodounou^{1,2}, Euloge Sènan Adjou^{1,2*}, Cyrille Oscar Adantchédé Akotowanou^{1,2}, Adéyèmi Bérane Olubi^{1,2}, Daniel Chougourou², Akadiri Yessoufou¹, Lamine Said Baba-Moussa³, Dominique C. K. Sohounhloué²

¹Laboratory of Integrative Biology for Therapeutic Innovation, Faculty of Sciences and Technology, Institute of Applied Biomedical Sciences, University of Abomey-Calavi (UAC), Cotonou, Benin

²Laboratory of Study and Research in Applied Chemistry, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, Cotonou, Benin

³Laboratory of Biology and Molecular Typing in Microbiology, Faculty of Science and Technology, University of Abomey-Calavi, Cotonou, Benin

Email: *eulogeadjou1@gmail.com

How to cite this paper: Vodounou, A., Adjou, E.S., Akotowanou, C.O.A., Olubi, A.B., Chougourou, D., Yessoufou, A., Baba-Moussa, L.S. and Sohounhloué, D.C.K. (2025) Kinetics of Enzyme-Assisted Extraction of Tigernut Milks (*Cyperus esculentus* L.) Using Mixture of Pectinases, Hemicellulases and β -Glucanases. *Advances in Molecular Imaging*, 14, 49-59.
<https://doi.org/10.4236/ami.2025.144004>

Received: May 25, 2025

Accepted: October 28, 2025

Published: October 31, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Tigernut tubers (*Cyperus esculentus*) are used to produce vegetable milk, however, the presence of pectic substances in the tuber limits the yield of the milk. The present study aims to improve the yields and extraction practice of milk by hydrolysis of pectic substances, using pectinolytic enzymes. The obtained results show that the use of enzymes (Pectinex Ultra SP-L) improves the extraction yields of tigernut milk depending on temperature and incubation times. The highest tigernut milk extraction yields ($86.2\% \pm 1.6\%$ for brown morphotype and $88.7\% \pm 0.6\%$ for yellow morphotype) are obtained at 60°C after 90 minutes of incubation. Results of physicochemical characterization of tigernut milks obtained also indicate that the use of an enzyme improves the physicochemical characteristics of the tigernut enzyme-assisted extraction milks compared to the controls. This technical approach makes it possible to produce tigernut milk of good physicochemical quality, which could easily be used by food industries.

Keywords

Cyperus esculentus, Enzymes, Vegetable Milk, Physicochemical

1. Introduction

In developing countries, apart from agriculture, livestock and fishing, the collection of non-timber forest products constitutes an important source of income for rural communities [1]. They are also true cultural markers of human history [2]. However, among these plant resources, there are forest and herbaceous species whose fruits or tubers are poorly valued and rot each year in large quantities [3] [4], and also create environmental nuisances. Thus, despite all their potential, these agricultural resources are gradually abandoned by populations. Added to this are also threats from anthropogenic origin, in particular demographic pressure, deforestation, wildfires, livestock breeding and also climate change, which contribute to the loss of many unvalued wild species [5]. In Benin, annual losses in forest cover are estimated at more than 50,000 ha, resulting in the disappearance of useful plant species from their natural ecosystems [6]. Therefore, it is not only important to define strategies for sustainable management and conservation of forest ecosystems, but also to consider processes for valorizing these plant species, while considering human needs.

Among the species that are undervalued in Benin is Tigernut (*Cyperus esculentus* L.), which is a perennial herbaceous plant with clonal growth, belonging to the Cyperaceae family [7]. According to Zhang *et al.* [8], mainly two varieties of *Cyperus esculentus* L., with tubers of different colors are encountered in West African countries. These are black and yellow morphotypes.

Tigernut has a high content of dietary fiber and is effective in the treatment and prevention of many diseases, including colon cancer [9]. However, its use is much more limited to direct consumption in roasted form or incorporated into sweet dishes [10]. In northern Brazil, Tigernut is used by the population, as an aphrodisiac and antivenom. They are also used to treat measles and fever, but generally as a dessert due to their sweet flavor [11].

In Benin, tigernut is used in traditional medicine in the treatment of lethargy, indigestion, diarrhea, dysentery, sexual infertility and excessive thirst [12]. Many authors have shown that *Cyperus esculentus* L. is an edible plant which produces tubers containing an important starch quantity (about 30% - 40%) [13]. Despite the high starch content of tigernut tubers, there is very little industrial valorization of this available food resource in Benin, which results in the significant post-harvest losses recorded each year. It is therefore important to consider the industrial valorization of this plant species by the production of tiger nut milk using biotechnological processes such as enzymatic catalysis.

Pectin, an essential polymer in plants, ensures the integrity and cohesion of their tissues. Tubers contain a high level of pectin, which contributes to their firmness and the texture of their cell walls. Therefore, in industrial processes aimed at

breaking down cell walls and releasing cell contents, pectinolytic enzymes could be of great use.

2. Material and Methods

2.1. Lant Material Collection

The ripe tubers of *Cyperus esculentus* L. (yellow and brown morphotypes) (**Figure 1**) were collected in the markets of the locality of Natitingou (Northern Benin). The fresh tigernut tubers were spread under sunlight on an inert surface to dry-up to a constant weight sample referred to as dried tigernut tubers.



Figure 1. Tigernut (*Cyperus esculentus* L.). ((a) *Yellow morphotype*, (b) *Brown morphotype*).

2.2. Enzymes

The enzyme complex used in the study is Pectinex Ultra SP-L, which is a multi-enzyme mixture of Pectinases, Hemicellulases and β -Glucanases, marketed by the firm Novozymes (Denmark).

2.3. Enzyme-Assisted Extraction of Tigernut Milks

The methodology used for the extraction of tiger nut milks is that described by Belewu and Abodunrin [14]. Indeed, the tigernut tubers collected were sorted and then washed. The tigernuts thus washed were divided into two batches. The first batch (control) is soaked in water (6 L/kg) for 18 hours in order to soften them. The second batch is divided into 4 groups labelled A, B, C and D. The soaking water used in this case (pH 6.8) was inoculated with the enzyme (Pectinex Ultra SP-L) at a concentration of 1 mL/L. The soaked tigernuts were incubated at 30°C, 40°C, 50°C and 60°C for 18 hours respectively. After soaking (18 hours), the tiger nuts were crushed and then ground using a Moulinex (Unitech Germany NSR 2025), and pressed to extract the milk. The extraction yields based on the ratio of milk weight to initial dry tuber weight, are then determined by the method described by Ezoua *et al.* [3] and Adjou *et al.* [15]. The different tiger nut milks extracted were then characterized. **Figure 2** indicated the technological diagram used for enzyme-assisted extraction of tigernut milk.

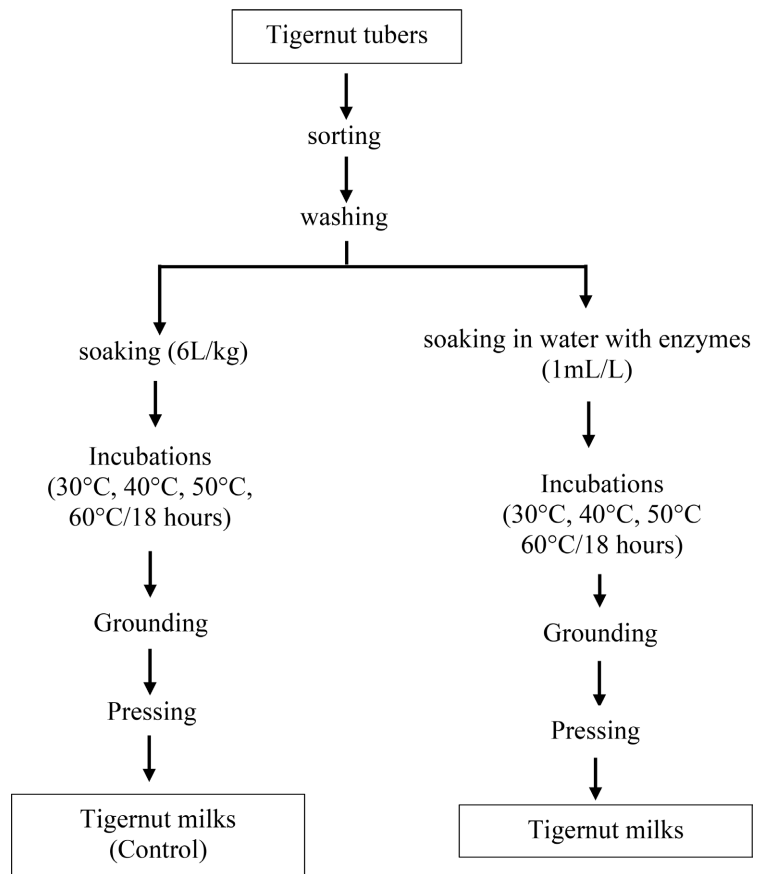


Figure 2. Technological diagram used for enzyme-assisted extraction of tigernut milk.

2.4. Physicochemical Characterization of Tigernut Milks

The pH was determined by direct measurement using a pH meter (HANNA 211), previously calibrated with buffer solutions of pH 4.0 and 7.0 [16]. Relative density was evaluated as described by Novidzro *et al.* [17]. The Brix was determined using a Novex Holland type digital refractometer [18]. Total titratable acidity (At) was determined according to the standard method described by Amoa-Awua *et al.* [19].

2.5. Statistical Analysis

Experiments were performed in triplicate, and data analyzed are means subjected to one-way Anova. Means are separated by the Tukey's multiple range test when Anova was significant ($P < 0.05$) (SPSS 10.0; Chicago, IL, USA).

3. Results and Discussion

Results of the extraction kinetics of milk from brown and yellow morphotypes of tigernuts are presented in **Figure 3** and **Figure 4**. These results indicated that in the absence of enzyme (control samples), the extraction yields are $60.54\% \pm 1.07\%$ for brown morphotype of tigernuts and $63.71\% \pm 1.14\%$ for yellow morphotype of tigernuts. These extraction yields are relatively lower than those reported by

Djomdi *et al.* [20] in Cameroon. This difference in yield could be due to the agro-pedological characteristics of the production area of the different tigernut samples used. However, results obtained during enzyme-assisted extraction of tigernut milks indicated that the use of the enzymes significantly influences ($p < 5\%$) the extraction yields of the milks. Indeed, the monitoring of the enzymatic kinetics of tigernut milk extraction indicated that with incubation temperatures of 50°C and 60°C, a significant increase ($p < 5\%$) in extraction yields is observed after an incubation time of 90 minutes. High tigernut milks extraction yields ($86.2\% \pm 1.6\%$ for brown morphotype and $88.7\% \pm 0.6\%$ for yellow morphotype) are obtained after 90 minutes of incubation at a temperature of 60°C.

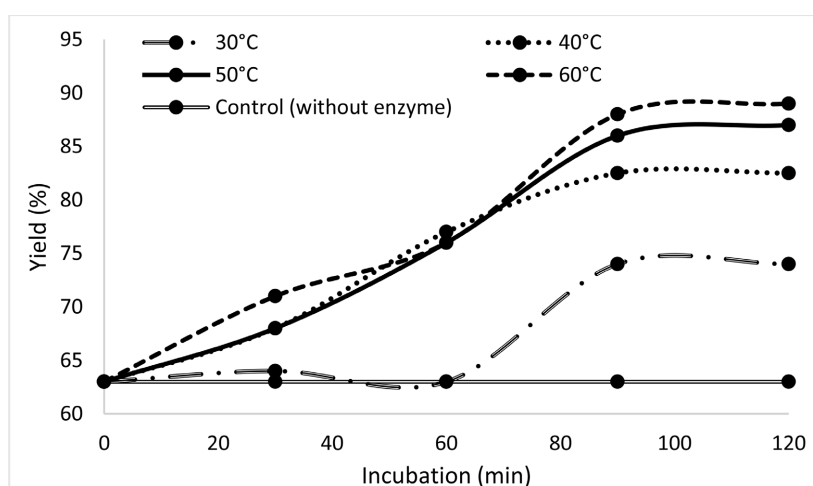


Figure 3. Kinetics of enzyme-assisted extraction milks from tigernut tubers (yellow morphotype).

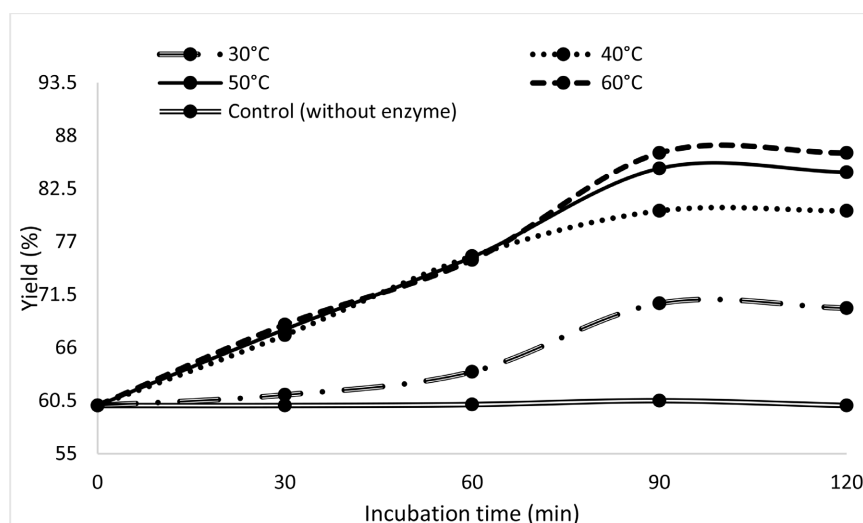


Figure 4. kinetics of enzyme-assisted extraction milks from tigernut tubers (brown morphotype).

On the other hand, at incubation temperatures of 30°C and 40°C, tigernut milks extraction yields are relatively lower despite the use of enzymes. These results

therefore indicated that enzymes (Pectinex Ultra SP-L) exert a catalytic activity on tigernut tuber grinds, dependent on the temperature and incubation time. Djomdi *et al.* [20] also reported tigernut milk extraction yield of 85% in the presence of enzyme (Termamyl). Similar yields were also reported by Jaisut *et al.* [21] and Klang *et al.* [22], in the enzymatic extraction of starch from rice and sorghum. Due to the high demand for various health outcomes, specific demands for functional foods have emerged during the post-pandemic period, particularly the categories of probiotics and prebiotics [23]. The incorporation of these food products into human diet can reduce the incidence of diseases resulting from metabolic syndrome, such as obesity [24].

Indeed, according to WHO, from 2018 to 2030, the number of obese children will reach from 150 to 250 billion [25], because dysbiosis initiates higher absorption of sugars in the small intestine by modulating membrane transport [26]. These challenges invite scientists to seek the development of sustainable and functional food products. In that case, the used of enzymes for the extraction of biomolecules from plants with a higher extraction yield, associated with the reduction of saccharification and viscosity can make easier the further processing operations, and make bioavailable vitamins and trace elements necessary for the good functioning of cellular metabolism. Similarly, recent studies [27] [28] have reported that enzyme-assisted extraction could lead to higher nutrient content in the extracts. In addition to releasing secondary metabolites and small peptides, enzymes hydrolyzed long-chain molecules into shorter and soluble molecules, facilitating subsequent transformation operations [29]. Secondary metabolites found in plants, are also associated with a reduced risk of obesity, because they can improve leptin and insulin sensitivity and modulate appetite. Indeed, Leptin is a hormone produced by fat cells that regulates appetite by signaling satiety to the brain, particularly the hypothalamus. Its role is to reduce the urge to eat when the body has sufficient stored energy. In overweight individuals, leptin resistance often develops, which can lead to increased hunger and overeating. Similarly, certain secondary metabolites can help to improve cell sensitivity to insulin, which is crucial for regulating blood sugar and preventing obesity. In addition to all this, plant-based milk, as substitutes for dairy milk, are one of the fastest-growing commodities in the food industry [30]. The rise in milk allergies, lactose intolerance, environmental concerns, and high-cholesterol diets has led to increased demand for the development of a variety of dairy alternatives [31].

Results obtained during the evaluation of the physicochemical characteristics of the different tigernut milks obtained by enzyme-assisted extraction are presented in **Tables 1-4**. The analysis of the results obtained indicated that the use of the enzymes (Pectinex Ultra SP-L), influences the physicochemical characteristics of the different of tigernut milks obtained. Indeed, the results of the pH evaluation of the different tigernut milks obtained using enzymes (**Table 1**) indicated that, with tigernut from yellow morphotype, the pH decreases from 6.48 ± 0.04 (pH of the milks extracted from the tigernuts tubers incubated with enzymes at 30°C

Table 1. pH of different tigernut milks obtained.

Temperature	Tigernut milks	Incubation time with enzymes				Control (without enzyme)
		30 minutes	60 minutes	90 minutes	120 minutes	
30°C	Yellow morphotype	6.48 ± 0.04 ^a	6.46 ± 0.05 ^a	6.18 ± 0.02 ^a	6.12 ± 0.01 ^a	6.52 ± 0.07 ^a
	Brown morphotype	6.42 ± 0.11 ^a	6.40 ± 0.01 ^a	6.17 ± 0.04 ^a	6.10 ± 0.03 ^a	6.47 ± 0.01 ^a
40°C	Yellow morphotype	6.39 ± 0.02 ^a	6.37 ± 0.04 ^a	6.20 ± 0.05 ^a	6.18 ± 0.07 ^a	6.51 ± 0.07 ^a
	Brown morphotype	6.37 ± 0.04 ^a	6.29 ± 0.06 ^a	6.14 ± 0.07 ^a	6.09 ± 0.05 ^a	6.47 ± 0.04 ^a
50°C	Yellow morphotype	6.28 ± 0.02 ^b	6.14 ± 0.01 ^b	5.68 ± 0.11 ^b	5.66 ± 0.09 ^b	6.52 ± 0.07 ^a
	Brown morphotype	6.12 ± 0.03 ^b	6.09 ± 0.07 ^b	5.61 ± 0.09 ^b	5.60 ± 0.06 ^b	6.47 ± 0.04 ^a
60°C	Yellow morphotype	6.08 ± 0.07 ^b	5.91 ± 0.02 ^b	5.86 ± 0.01 ^b	5.87 ± 0.02 ^b	6.52 ± 0.01 ^a
	Brown morphotype	6.04 ± 0.01 ^b	5.87 ± 0.04 ^b	5.72 ± 0.07 ^b	5.62 ± 0.09 ^b	6.47 ± 0.03 ^a
Significativity		*	*	*	*	0

Values are means (n = 3). Means with the same letter in the same column are not statistically different according to the ANOVA test and Tukey's multiple comparison test at the 5% level; 0 = p > 0.05 (not significant); *p < 0.05 (significant).

Table 2. Acidity (%) of different tigernut milks obtained.

Temperature	Tigernut milks	Incubation time with enzymes				Control (without enzyme)
		30 minutes	60 minutes	90 minutes	120 minutes	
30°C	Yellow morphotype	0.131 ± 0.004 ^a	0.133 ± 0.011 ^a	0.152 ± 0.013 ^a	0.156 ± 0.017 ^a	0.122 ± 0.041 ^a
	Brown morphotype	0.136 ± 0.017 ^a	0.139 ± 0.010 ^a	0.164 ± 0.012 ^a	0.166 ± 0.011 ^a	0.127 ± 0.011 ^a
40°C	Yellow morphotype	0.141 ± 0.016 ^a	0.144 ± 0.016 ^a	0.171 ± 0.017 ^a	0.174 ± 0.019 ^a	0.121 ± 0.053 ^a
	Brown morphotype	0.146 ± 0.011 ^a	0.149 ± 0.017 ^a	0.181 ± 0.014 ^a	0.189 ± 0.012 ^b	0.126 ± 0.014 ^a
50°C	Yellow morphotype	0.161 ± 0.019 ^b	0.178 ± 0.011 ^b	0.191 ± 0.022 ^b	0.194 ± 0.025 ^b	0.121 ± 0.046 ^b
	Brown morphotype	0.167 ± 0.012 ^b	0.175 ± 0.016 ^b	0.197 ± 0.011 ^b	0.197 ± 0.014 ^b	0.127 ± 0.011 ^b
60°C	Yellow morphotype	0.161 ± 0.015 ^b	0.167 ± 0.012 ^b	0.198 ± 0.014 ^b	0.211 ± 0.007 ^c	0.122 ± 0.036 ^b
	Brown morphotype	0.164 ± 0.011 ^b	0.171 ± 0.014 ^b	0.196 ± 0.015 ^b	0.241 ± 0.017 ^c	0.127 ± 0.011 ^b
Significativity		*	*	*	*	*

Values are means (n = 3). Means with the same letter in the same column are not statistically different according to the ANOVA test and Tukey's multiple comparison test at the 5% level; 0 = p > 0.05 (not significant); *p < 0.05 (significant).

Table 3. Brix (°Bx) of different tigernut milks obtained.

Temperature	Tigernut milks	Incubation time with enzymes				Control (without enzyme)
		30 minutes	60 minutes	90 minutes	120 minutes	
30°C	Yellow morphotype	6.43 ± 0.06 ^a	6.43 ± 0.11 ^a	7.12 ± 0.09 ^a	7.13 ± 0.02 ^a	6.43 ± 0.26 ^a
	Brown morphotype	6.39 ± 0.17 ^a	6.41 ± 0.13 ^a	6.91 ± 0.09 ^a	6.93 ± 0.17 ^a	6.37 ± 0.11 ^a
40°C	Yellow morphotype	6.44 ± 0.23 ^a	6.52 ± 0.06 ^a	7.33 ± 0.12 ^a	7.23 ± 0.07 ^a	6.42 ± 0.17 ^a
	Brown morphotype	6.41 ± 0.07 ^a	6.49 ± 0.16 ^a	7.13 ± 0.17 ^a	7.17 ± 0.09 ^a	6.36 ± 0.02 ^a

Continued

50°C	Yellow morphotype	6.57 ± 0.06 ^b	7.48 ± 0.21 ^b	9.13 ± 0.04 ^b	9.14 ± 0.16 ^b	6.41 ± 0.21 ^b
	Brown morphotype	6.51 ± 0.04 ^b	7.43 ± 0.06 ^b	8.97 ± 0.01 ^b	9.03 ± 0.07 ^b	6.33 ± 0.17 ^b
60°C	Yellow morphotype	6.59 ± 0.01 ^b	7.51 ± 0.11 ^b	9.16 ± 0.07 ^b	9.17 ± 0.04 ^b	6.42 ± 0.16 ^b
	Brown morphotype	6.57 ± 0.04 ^b	7.49 ± 0.08 ^b	9.03 ± 0.14 ^b	9.07 ± 0.01 ^b	6.32 ± 0.09 ^b
Significativity		*	*	*	*	*

Values are means (n = 3). Means with the same letter in the same column are not statistically different according to the ANOVA test and Tukey's multiple comparison test at the 5% level; 0 = p > 0.05 (not significant); *p < 0.05 (significant).

Table 4. Density of different tigernut milks obtained.

Temperature	Tigernut milks	Incubation time with enzymes				Control (without enzyme)
		30 minutes	60 minutes	90 minutes	120 minutes	
30°C	Yellow morphotype	1.91 ± 0.14 ^a	1.90 ± 0.07 ^a	1.84 ± 0.02 ^a	1.83 ± 0.04 ^a	1.89 ± 0.14 ^a
	Brown morphotype	1.86 ± 0.07 ^a	1.83 ± 0.01 ^a	1.76 ± 0.13 ^a	1.71 ± 0.07 ^a	1.85 ± 0.03 ^a
40°C	Yellow morphotype	1.83 ± 0.21 ^b	1.81 ± 0.07 ^b	1.64 ± 0.13 ^b	1.62 ± 0.27 ^b	1.87 ± 0.11 ^b
	Brown morphotype	1.81 ± 0.13 ^b	1.76 ± 0.01 ^b	1.60 ± 0.17 ^b	1.60 ± 0.21 ^b	1.86 ± 0.09 ^b
50°C	Yellow morphotype	1.89 ± 0.11 ^a	1.74 ± 0.13 ^a	1.43 ± 0.017 ^a	1.42 ± 0.04 ^a	1.88 ± 0.13 ^a
	Brown morphotype	1.85 ± 0.02 ^a	1.67 ± 0.04 ^a	1.47 ± 0.06 ^a	1.43 ± 0.02 ^a	1.85 ± 0.04 ^a
60°C	Yellow morphotype	1.81 ± 0.13 ^b	1.61 ± 0.02 ^b	1.41 ± 0.03 ^b	1.36 ± 0.07 ^b	1.81 ± 0.05 ^b
	Brown morphotype	1.82 ± 0.07 ^b	1.81 ± 0.09 ^b	1.40 ± 0.07 ^b	1.41 ± 0.01 ^b	1.88 ± 0.16 ^b
Significativity		*	*	*	*	*

Values are means (n = 3). Means with the same letter in the same column are not statistically different according to the ANOVA test and Tukey's multiple comparison test at the 5% level; 0 = p > 0.05 (not significant); *p < 0.05 (significant).

during 30 minutes) to 5.87 ± 0.02 (pH of the milks extracted from the tigernut tubers incubated with enzyme at 60°C for 120 minutes). However, with tigernut tubers from brown morphotype, the pH decreases from 6.42 ± 0.11 (pH of milks extracted from tigernut tubers incubated with enzymes at 30°C for 30 minutes) to 5.62 ± 0.09 (pH of milks extracted from tigernut tubers incubated with enzymes at 60°C for 120 minutes). In the other hand, results obtained (**Table 2**) indicated the increase of the acidity of tigernut milks obtained from enzyme-assisted extraction, when compared to the control (without enzyme). This increase in titratable acidity could be due to the release of galacturonic acid molecules during the hydrolysis of macromolecules under the action of pectinases [3, 15]. This observation is also confirmed by the low acidity of juices extracted without enzymes. Similarly, results obtained during the monitoring of the Brix (**Table 3**) and the Density (**Table 4**) of the different tigernut tuber milks obtained by enzyme-assisted extraction, also indicated the increase of these parameters when compared to the control. According to Prathyusha and Suneetha [32], the pectinolytic activity of enzymes, especially hydrolases lies in their ability to increase the destruction of

cell walls of pulps and to ensure better extraction of cellular content [33]. This ability of pectinolytic enzymes could explain the observed increase in Brix and Density of enzyme-assisted extraction of Tigernut milks.

4. Conclusion

The present study indicates that the enzymatic complex used improves significantly the extraction yield of tigernut milk, regardless of the morphotype, but depending on the temperature and incubation time. Enzymatic treatment of tigernut tubers also improved the physicochemical characteristics of tigernut milk obtained, compared to milk from untreated tigernuts. These findings therefore constitute an interesting advance that can be exploited by food industries interested in the valorization of tigernut milk. Further studies may also focus on the research for natural antimicrobial products effective in the sustainable preservation of tigernut milk, because of their high content of nutrients that could be used by food spoilage microorganisms.

Acknowledgements

The authors thank their respective laboratories for technical support.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Savvides, A.M., Stavridou, C., Ioannidou, S., Zoumides, C. and Stylianou, A. (2023) Une enquête ethnobotanique sur les usages traditionnels des plantes médicinales et aromatiques méditerranéennes: Le cas des montagnes du Troodos à Chypre. *Plantes*, **12**, 11-19.
- [2] Vodounou, A., Adjou, E.S., Kplaïssa, F.M., Dahouenon-Ahoussi, E., Sohounhloue, D.C.K. (2022) Valorization of Wild Fruits for Human Nutrition in Demographic Pressure Challenges: Perception of Fruit Traders on Plants Species under Anthropogenic Threats. *International Journal of Frontiers in Life Science Research*, **3**, 1-6. <https://doi.org/10.53294/ijflsr.2022.3.2.0066>
- [3] Ezoua, P., Kouamé, D. and Agbo, N.G. (1999) Caractéristique du jus de la pulpe fraîche du fruit de rônier (*Borassus Aethiopum* Mart). *Cahiers Agricultures*, **8**, 126-128.
- [4] Gbohaida, V., Mossi, I., Adjou, E.S. and Sohounhloue, D.C.K. (2016) Évaluation du pouvoir fermentaire de *Saccharomyces cerevisiae* et de *S. carlsbergensis* dans la production de bioéthanol à partir du jus de la pomme cajou. *Journal of Applied Biosciences*, **101**, 9643-9652.
- [5] Adomou, A., Yedomonhan, H., Djossa, B., Legba, S., Oumorou, M. and Akoegninou, A. (2012) Etude Ethnobotanique des plantes médicinales vendues dans le marché d'Abomey-Calavi au Bénin. *International Journal of Biological and Chemical Sciences*, **6**, Article 745772. <https://doi.org/10.4314/ijbcs.v6i2.18>
- [6] Assogbadjo, A., Gouwakinnou, G., Djagoun, C. S., Akpona, J-D., Salako, V., Idohou R., Déguénonvo, N., Akpona, H. and Akouehou G. (2014) Cinquième rapport national sur la mise en œuvre de la convention sur la diversité biologique au Bénin. *Direction*

Générale des Forêts et des Ressources Naturelles. Ministre de l'Environnement chargé de la Gestion des Changements Climatiques, du Reboisement et de la Protection des Ressources Naturelles et Forestières. 109 p.

<https://www.cbd.int/doc/world/bj/bj-nr-05-fr.pdf>

- [7] Li, M., Wedin, D.A. and Tieszen, L.L. (1999) C₃ and C₄ Photosynthesis in *Cyperus* (Cyperaceae) in Temperate Eastern North America. *Canadian Journal of Botany*, **77**, 209-218. <https://doi.org/10.1139/b98-216>
- [8] Zhang, Y., Kan, H., Chen, S., Thakur, K., Wang, S., Zhang, J., *et al.* (2020) Comparison of Phenolic Compounds Extracted from Diaphragma Juglandis Fructus, Walnut Pellicle, and Flowers of Juglans Regia Using Methanol, Ultrasonic Wave, and Enzyme Assisted-Extraction. *Food Chemistry*, **321**, Article 126672. <https://doi.org/10.1016/j.foodchem.2020.126672>
- [9] Adejuyitan, J.A. (2002) Transformation du souchet: Ses utilisations alimentaires et ses bienfaits pour la santé. *American Journal of Food Technology*, **6**, Article 197201.
- [10] Defelice, M.S. (2002) Yellow Nutsedge *Cyperus esculentus* L.—Snack Food of the Gods. *Weed Technology*, **16**, 901-907. [https://doi.org/10.1614/0890-037x\(2002\)016\[0901:yncels\]2.0.co;2](https://doi.org/10.1614/0890-037x(2002)016[0901:yncels]2.0.co;2)
- [11] Matos, F.J., Cavalcanti, F.S. and Parente, J.P. (2008) Qualitative and Quantitative Agronomic Study of *Cyperus esculentus* L. (Earth Almond)—An Unexplored Source of Energetic Food. *Revista Ciencia Agronomica*, **39**, 124-129.
- [12] Adjahossou, V.N., Gbemavo, D.S.J.C., Abidja, S., Laly, J., Gbaguidi, A.A. and Dansi Anagonou, A. (2021) Classification populaire et usages traditionnels de *Cyperus esculentus*, une espèce négligée et sous-utilisée au Bénin. *Biodiversitas Journal of Biological Diversity*, **22**, 2972-2979. <https://doi.org/10.13057/biodiv/d220750>
- [13] Djomdi, D., Kramer, J.K.G., VanderJagt, D.J., Ejoh, R., Ndjouenkeu, R. and Glew, R.H. (2013) Influence of Soaking on Biochemical Components of Tiger Nut (*Cyperus esculentus*) Tubers Cultivated in Cameroon. *International Journal of Food Processing Engineering*, **1**, 16-28.
- [14] Belewu, M.A. and Abodunrin, O.A. (2008) Preparation of Kunnu from Unexploited Rich Food Source: Tiger Nut (*Cyperus esculentus*). *Pakistan Journal of Nutrition*, **7**, 109-111. <https://doi.org/10.3923/pjn.2008.109.111>
- [15] Adjou, E., Amamion, H., Tchobo, F., Aissi, V. and Soumanou, M. (2013) Extraction assistée par enzyme du jus de la pulpe fraîche du rônier (*Borassus aethiopum* Mart.) acclimaté au Benin: Caractérisation physico-chimique et microbiologique. *International Journal of Biological and Chemical Sciences*, **7**, 1135-1146. <https://doi.org/10.4314/ijbcs.v7i3.20>
- [16] AOAC International (2000) Official Methods of Analysis of AOAC International. 17th Edition, Association of Analytical Communities.
- [17] Novidzro, K.M., Agbodan, K.A. and Koumaglo, K.H. (2013) Etude de la performance de quatre souches de *saccharomyces cerevisiae* au cours de la production d'éthanol à partir des moûts de sucrose enrichis. *Journal de la Société Ouest-Africaine de Chimie*, **35**, 1-7.
- [18] Gbohaïda, V., Konfo, T.R.C., Adjou, E.S., Wotto, D.V., Avlessi, F. and Sohounhloué, D.C.K. (2013) Assessment of Biofuel Potential of the Red Variety of Cashew Apple. *Journal of Chemical, Biological and Physical Sciences*, **13**, 17-28.
- [19] Amoa-Awua, W.K.A., Appoh, F.E. and Jakobsen, M. (1996) Lactic Acid Fermentation of Cassava Dough into Agbelima. *International Journal of Food Microbiology*, **31**, 87-98. [https://doi.org/10.1016/0168-1605\(96\)00967-1](https://doi.org/10.1016/0168-1605(96)00967-1)
- [20] Djomdi, D., Pierre, G., Hamadou, B., Gibert, O., Tran, T., Delattre, C., *et al.* (2020)

- Innovation in Tigernut (*Cyperus esculentus* L.) Milk Production: *In Situ* Hydrolysis of Starch. *Polymers*, **12**, Article 1404. <https://doi.org/10.3390/polym12061404>
- [21] Jaisut, D., Prachayawarakorn, S., Varayanond, W., Tungtrakul, P. and Soponronarit, S. (2008) Effects of Drying Temperature and Tempering Time on Starch Digestibility of Brown Fragrant Rice. *Journal of Food Engineering*, **86**, 251-258. <https://doi.org/10.1016/j.jfoodeng.2007.10.002>
- [22] Klang, M.J., Talamond, P., Djidimbele, N., Tavea, F. and Ndjouenkeu, R. (2014) Partial Purification and Characterization of α -Amylases from *Abrus Precatorius*, *Bunatia Enneandra* and *Cadaba Farinosa*. *Journal of Enzyme Research*, **1**, 66-71.
- [23] Cunningham, M., Vinderola, G., Charalampopoulos, D., Lebeer, S., Sanders, M.E. and Grimaldi, R. (2021) Applying Probiotics and Prebiotics in New Delivery Formats—Is the Clinical Evidence Transferable? *Trends in Food Science & Technology*, **112**, 495-506. <https://doi.org/10.1016/j.tifs.2021.04.009>
- [24] Streimikyte, P., Viskelis, P. and Viskelis, J. (2022) Enzymes-Assisted Extraction of Plants for Sustainable and Functional Applications. *International Journal of Molecular Sciences*, **23**, Article 2359. <https://doi.org/10.3390/ijms23042359>
- [25] Włodarczyk, M. and Śliżewska, K. (2021) Obesity as the 21st Century's Major Disease: The Role of Probiotics and Prebiotics in Prevention and Treatment. *Food Bioscience*, **42**, Article 101115. <https://doi.org/10.1016/j.fbio.2021.101115>
- [26] Tidjani Alou, M., Lagier, J. and Raoult, D. (2016) Diet Influence on the Gut Microbiota and Dysbiosis Related to Nutritional Disorders. *Human Microbiome Journal*, **1**, 3-11. <https://doi.org/10.1016/j.humic.2016.09.001>
- [27] Penha, C.B., Santos, V.D.P., Speranza, P. and Kurozawa, L.E. (2021) Plant-Based Beverages: Ecofriendly Technologies in the Production Process. *Innovative Food Science & Emerging Technologies*, **72**, Article 102760. <https://doi.org/10.1016/j.ifset.2021.102760>
- [28] Maduka, N. and Ire, F.S. (2019) A Review of Some Prevention Strategies against Contamination of *Cyperus Esculentus* and Tigernut-Derived Products of Economic Importance. *Asian Journal of Advanced Research and Reports*, **1**, 1-13. <https://doi.org/10.9734/ajarr/2019/v3i129792>
- [29] Ejoh, R.A. and Ndjouenkeu, R. (2006) Characteristics of Tigernut (*Cyperus esculentus*) Tubers and Their Performance in the Production of a Milky Drink. *Journal of Food Processing and Preservation*, **30**, 145-163. <https://doi.org/10.1111/j.1745-4549.2006.00056.x>
- [30] Sethi, S., Tyagi, S.K. and Anurag, R.K. (2016) Plant-Based Milk Alternatives an Emerging Segment of Functional Beverages: A Review. *Journal of Food Science and Technology*, **53**, 3408-3423. <https://doi.org/10.1007/s13197-016-2328-3>
- [31] Haas, R., Schnepps, A., Pichler, A. and Meixner, O. (2019) Cow Milk versus Plant-Based Milk Substitutes: A Comparison of Product Image and Motivational Structure of Consumption. *Sustainability*, **11**, Article 5046. <https://doi.org/10.3390/su11185046>
- [32] Prathyusha, K. and Suneetha, V. (2011) Bacterial Pectinases and Their Potent Biotechnological Application in Fruit Processing/Juice Production Industry: A Review. *Journal of Phytology*, **3**, 6-19.
- [33] Verma, H., Narnoliya, L.K. and Jadaun, J.S. (2018) Pectinase: A Useful Tool in Fruit Processing Industries. *Nutrition & Food Science International Journal*, **5**, Article 555673. <https://doi.org/10.19080/nfsij.2018.05.555673>