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Original Research Article

Evaluating Cashew Tree Gum as A Potential Vaccine Carrier: Purification, Phytochemical Analysis and Biocompatibility Assessment

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ABSTRACT

Effective vaccine delivery is crucial for controlling infectious diseases. Natural polymers are increasingly considered in drug delivery systems due to their low cost, biocompatibility, biodegradability, safety and dose sparing. Despite these advantages, there is limited information on their use in veterinary applications. This study explores cashew tree gum (CTG) as a potential vaccine carrier, especially in veterinary setting, focusing on its purification, phytochemical profile, and biocompatibility. Cashew tree gum was harvested from incisions in the tree trunk, followed by a purification process. Phytochemical analysis, rheological properties, and proximate and metallic content were assessed using standard methods. The viscosity was measured with a Brookfield viscometer, and pH values were determined using a Jenway 3510 pH meter. Data were analyzed using one-way ANOVA with MiniTab Version 9.5. The purification process yielded 81.61%. The purified gum exhibited a glassy white colour, odourless smell, and bland taste. The pH values for crude and purified gums were 3.91 and 4.08, respectively. Moisture content was 0.08% in crude gum and 0.13% in purified gum, while total solids were 99.92%. Ash content was 0.999% for crude gum and 0.565% for purified gum. The gum contained glycosides, tannins, alkaloids, and triterpenoids, with no detectable heavy metals. Essential minerals such as sodium, potassium, iron, zinc, calcium, and manganese were present at concentrations within acceptable ranges. Cashew tree gum shows significant promise as a vaccine carrier due to its high yield, safe phytochemical profile, and biocompatibility; therefore, can be used in advancing oral vaccine delivery.

Keywords: Cashew tree gum, Vaccine carrier, Biocompatibility, Phytochemical analysis, Purification.

Introduction

Vaccines have been a cornerstone in the global fight against infectious diseases, significantly enhancing public health outcomes.[1,2] Despite their critical role, vaccine efficacy can be limited by challenges such as poor immunogenicity due to gut and environmental conditions and method of delivery.[3] To address these challenges, there is the need to develop carriers, especially from natural polymers, which have shown promise in drug delivery systems due to their availability, low cost, biocompatibility, low toxicity, and biodegradability.[4-6]

Drug delivery systems using polymers have been the focus in recent times, because polymers have been shown to have good flow characteristics and compressibility, making it suitable as a diluent for tablet formulations. Studies by Loureiro *et al.*.[7] Nandi and Mukhopadhyay ,[8] Pinto *et al.* ,[9] and Silva *et al.* [10] explored the use of polymers as a potential drug delivery system and pharmaceutical excipient. They were employed in the fabrication of various micro- and nanostructured drug delivery devices, including nanoparticles. Nanoparticles from natural polymers are known to effectively encapsulate drugs and provide sustained release.[8] These studies make natural polymers promising candidates for other pharmaceutical applications. However, there is paucity of information on their application as vaccine carriers in veterinary subjects. This study seeks to address the challenges faced by the poultry industry in controlling Newcastle disease by exploring innovative vaccine delivery systems. Given the economic importance of the poultry sector and the significant impact of Newcastle disease on productivity, there is a critical need to develop more effective and sustainable vaccination strategies. This research seeks to provide a solution to the limitations of current vaccination methods and improve disease management within the poultry industry.

This study focuses on Cashew tree gum [CTG], a biocompatible and biodegradable natural polysaccharide, as a potential vaccine carrier. Primarily, the aim is to evaluate CTG through purification, phytochemical analysis, and biocompatibility assessment, contributing to the development of safer and more effective vaccine carrier and delivery systems. The current study's objectives are to purify CTG for pharmaceutical use, identify its constituents through phytochemical analysis, and evaluate its biocompatibility as a vaccine carrier. Biocompatibility is paramount in drug development to avoid adverse reactions.[26, 27] Our study underscores the importance of evaluating CTG's safety and compatibility as a vaccine carrier.

Cashew tree gum [CTG], a natural polysaccharide derived from the stem bark of the cashew tree (*Anacardium occidentale* L.), is notable for its diverse applications.[11-15] With properties such as mucoadhesion,

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controlled release, and biocompatibility, CTG has been explored for its suitability in drug delivery systems.[16-20] The gum's material properties, including surface morphology and thermal stability, have been studied, and its pharmacological activities, such as antidiarrheal and anti-inflammatory effects, have been documented.[17, 21]

The pharmaceutical industry's interest in CTG is due to its non-toxicity and biodegradability, with research exploring its use in various drug delivery systems. [15, 20] These properties make cashew gum a promising candidate for exploration as a vaccine carrier, as polymer carriers can enhance vaccine performance by improving immunogenicity and stability.[2, 22, 23] However, the full potential of CTG as a vaccine carrier has yet to be characterized. Our study seeks to fill this gap by providing a comprehensive evaluation of CTG's properties, and safety profile and to assess CTG as a vaccine carrier.

Materials and Methods

Collection and Preparation of Cashew Tree Gum

Crude Cashew tree gum [CTG] was obtained between May and August 2022 from the Ejura cashew plantation in the Ashanti Region of Ghana. The sample was verified by Prof Gustav Komlaga of the Department of Pharmacognosy, Faculty of Pharmacy and Pharmaceutical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi (KNUST), and assigned a specimen voucher number KNUST/HM1/2022/CG001. The sample is kept at Faculty of Pharmacy Herbarium, KNUST. For preparation for this study, the sample was dried, and sorted into two grades. The light-coloured grade was milled into a fine powder for subsequent analysis.

Purification Process

The gum was purified according to the process described by Ofori-Kwakye *et al.*.[17] Briefly, the crude gum powder was dispersed in distilled water, followed by filtration through a muslin cloth to remove insoluble impurities. The mucilage was then precipitated with ethanol, washed with diethyl ether, and dried in the microwave set to 60º C for 20 hours. The resulting dried purified gum was milled in a laboratory Blender [Multifunction Blender Robots, SC-1589, Silver Crest] and sieved to uniform particle size using a Laboratory Test sieve [Aperture 250Um, silver steel mesh] for further testing.

Determination of Percentage Yield

The percentage yield of the purification process was calculated as follows: the final weight of the purified gum, multiplied by 100 and divided by the initial weight of the crude gum.

For crude cashew tree gum [CTG] in this study, the percentage yield was calculated as the final weight of 81.61 g purified gum, multiplied by 100 and divided by the initial weight of 100 g.

Phytochemical Analysis

The phytochemical constitituents of the gum were determined according to methods described by Banu and Cathrine 2015.[24] These methods were employed and adapted to analyze the presence of tannins, flavonoids, saponins, glycosides, triterpenoids, coumarins and alkaloids in the CTG.

Physicochemical and Mineral Characterization

Proximate analysis was conducted to determine the protein, fat, moisture, ash, Fibre, and carbohydrate [Carbohydrate contents of the CTG using the official methods of analysis of the Association of Official Analytical Chemists [AOAC] methods.[25]

Moisture content was assessed by drying the gum at 105°C and measuring the loss on drying. The insoluble matter in both crude and purified gum was quantified after acid treatment and filtration. The pH of the gum mucilage was determined using a standardized pH meter [JENWAY 3510 pH Meter and Starter 3100], and mineral content was analysed using Microwave Plasma Atomic Emission Spectroscopy [MP-AES] after wet digestion with nitric and per chloric acids.

Rheological Properties

The effect of concentration on the viscosity of CTG mucilage was examined by preparing mucilage at various concentrations and measuring their viscosity using Brookfield Viscometer, by multiplying dial reading by factor as described by Ofori-Kwakye *et al*.[17] This assessment is crucial for understanding the behaviour of CTG in vaccine formulations. Briefly, different concentrations [5, 10, 20, 30, 40%] of CTG mucilage were prepared in a beaker and the viscometer probe was lowered into the mucilage and the reading taken on the dial panel.

Understanding CTG's physicochemical and biological properties is essential for assessing its safety and efficacy.

Statistical Analysis

Data obtained on the physicochemical parameters, metal content, and rheological properties of the cashew gum were subjected to a one-way analysis of variance [ANOVA] and means were separated using Tukey's test. Statistical significance was tested at a 5% significance level [95% confidence interval]. Significance values less than $p \leq 0.05$ were deemed to be statistically significant.

Results and Discussion

Purification Percentage Yield

The process of obtaining and purifying cashew tree gum begins with incising and harvesting cashew tree exudate. The fresh exudate is allowed to mature over time into a denser, more concentrated form on the tree. The matured exudate is sorted by quality, with the light grade, which is pale and containing fewer impurities and the dark grade darker and having moreimpurities.[17] The light grade is milled into finer particles and then purified to remove contaminants, resulting in refined cashew gum ready for use (Figure 1, A-F).The percentage yield was 81.61%. This purification yield indicates an effective removal of impurities and contaminants, with resultant pristine macroscopic features such as glassy white colour, inodorous smell, and amorphous form (Table 1). This refined form is a relatively pure product suitable for further analysis and potential applications. Purifying CTG is a multifaceted process influenced by factors such as contamination, yield, solubility, and the chosen purification technique. Successfully handling these factors is crucial for producing CTG of sufficient quality for use as a vaccine adjuvant or in drug delivery systems.

The purification of CTG is essential for its pharmaceutical applications. Methods vary, four of which were described by Loureiro *et al.*, 2021,[7] where the crude cashew gum was first dispersed in water and left for 24hours, followed by filtration and precipitation by either hydrogen peroxide, acetone, ethanol or sonicated in water by tip ultrasound. Alcohol precipitation was utilised in this study. Notably, the purification method, including alcohol precipitation, has been shown not to significantly affect CTG's biocompatibility.[17]

Proximate Composition

Raw cashew gum had moisture content of 0.13% ± 0.0093, while purified cashew gum showed slightly lower moisture of 0.08% ± 0.0078. Total solids were 99.87% ± 0.0093 in raw gum and slightly higher at 99.92% ± 0.0078 in purified gum. Total ash content differed non-significantly, with raw gum at 0.999% ± 0.1020 and purified gum at 0.565% ± 0.0058. Crude fat content was significantly [$p=0.047$] higher in purified gum [6.314% ± 0.2970] compared to raw gum [3.154% ± 0.1490] as shown in Table 2.

Purified gum also exhibited higher crude protein content [1.5712% ± 0.0153] compared to raw gum [1.927% ± 0.0209], which was statistically significant [$p=0.033$]. Nitrogen content was significantly [$p=0.033$] lower in purified gum [0.2514% ± 0.00245] compared to raw gum [0.308% ± 0.0033]. Carbohydrate content was slightly lower in purified gum [91.467% ± 0.3140] compared to raw gum [93.79% ± 0.2390], though not statistically significant [$p = 0.076$]. Proximate analysis revealed a low moisture content of 0.13% for the crude cashew gum, while the purified was 0.08%, these values are very low compared to other findings [15, 17] where 11.2% and 10.4% of crude and purified cashew gums were observed, respectively. This may be due to maturity of the cashew tree the

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gums were harvested, season of harvesting, and differences in drying processes employed during the sourcing and processing [purification] of the gum from the cashew tree.[15] A high total solids content of 99.92%, and stable mineral composition with total ash content of 0.999% and 0.565% in crude and purified cashew gums respectively, similar to other findings [15, 20,31-33] where the study found total ash of 0.5-1.2%. These findings indicate favourable properties for pharmaceutical applications, as the low moisture content minimizes the risk of microbial contamination and degradation of vaccine components during storage, while the high total solids content ensures a stable matrix for vaccine antigens, facilitating their uniform dispersion and controlled release upon administration and the low ash content indicates good quality of mineral content.[15]

Metal Content of Gum

The metal contents of the gum are presented in Table 3. The metal content analysis of cashew tree gum [CTG] provides critical insights into its safety and suitability for pharmaceutical applications, particularly as a potential vaccine carrier. The analysis revealed the presence of several metals, including iron, zinc, calcium, manganese, sodium, and potassium, in both raw and purified forms of CTG, in tandem with other findings.[15, 17, 31-33]

Metals such as iron, zinc, calcium, and manganese were present in CTG at concentrations within the normal range, posing no significant health risks. These metals are essential micronutrients required for various physiological functions in the body and are commonly found in plant-derived materials. Sodium and potassium content in CTG showed slight variations between raw and purified forms, with sodium exhibiting a statistically significant increase in purified gum. Sodium and potassium are essential electrolytes required for various physiological functions in the body, including nerve and muscle function, and are commonly found in plant-derived materials. The observed variations may reflect changes in the composition and structure of CTG during the purification process, which could influence its functional properties as a vaccine carrier.

Phytochemical Constituents

In the raw state, saponins, glycosides, tannins, triterpenoids, alkaloids, and coumarins were present, with saponins and glycosides being notably more abundant (Table 4). Conversely, in the purified state, saponins, glycosides, tannins, triterpenoids, and alkaloids were present, albeit with a slightly reduced presence compared to the raw state. Notably, sterols, flavonoids, and coumarins were absent in both raw and purified states of cashew gum. Phytochemicals, the bioactive compounds in plants, play a pivotal role in modulating immune responses.[28, 29, 31-33] They interact with immune system components, such as cells and cytokines, to exert various biological activities.[30] Antioxidant phytochemicals like flavonoids and polyphenols mitigate oxidative stress and inflammation, bolstering immune function. Anti-inflammatory compounds, including curcumin and quercetin, help combat chronic diseases, while antimicrobial phytochemicals, including alkaloids, offer protection against infectious diseases. In vaccine carrier formulations, certain phytochemicals have been instrumental in enhancing immune responses. Saponins, for instance, are used in vaccines like HPV and foot-and-mouth disease vaccines to boost both humoral and cell-mediated immunity. Similarly, coumarins exhibit immunostimulatory and anti-inflammatory properties. These findings underscore the potential of phytochemicals in vaccine carrier development and highlight the need for further research to optimize their use. The potential of phytochemicals in vaccine development is clear, but further research is needed to optimize their use.

Table 1: Macroscopic features of the gum

S/N	Feature	Characteristic
1	Colour	Glassy white
2	Odour	Inodorous
3	Taste	Bland
4	Form and shape	Amorphous
5	Brittleness	Depends on dryness

Rheological Findings

The swelling index of the raw cashew gum had a mean value of 3.20 ± 0.000, whereas purified cashew gum exhibited a significantly lower mean of 1.05 ± 0.070 [$p \leq 0.001$*] (Table 5). Further, raw cashew gum had an acidic pH value of 3.91 ± 0.005, while the purified cashew gum showed a slightly higher mean pH of 4.08 ± 0.017 [$p \leq 0.001$]. The pH levels of both crude and purified gums were slightly acidic, having 3.91 and 4.08 values respectively, supported by other findings that claimed the pH of cashew gums are usually within the range of 3.8 to 4.2.[15, 17] The pH of purified gum was slightly higher than raw gum, indicating a slight alkalization effect during the purification process. The swelling index of purified gum was significantly lower than raw gum, suggesting a reduction in water absorption and swelling capacity. The lower swelling index indicates effective purification and removal of impurities, leading to a more refined and homogeneous product suitable for vaccine formulation.

The viscosity profiles of the raw and purified gums are presented in Table 6. The effect of gum concentration on viscosity was also determined. For both the raw and purified gum samples, the viscosity generally increased with increasing gum concentration. However, there was significant difference in viscosity between raw and purified states, with the latter being less viscous. A lower viscosity will encourage an easier processing and administration of the gum-based vaccine. This may also enhance patient comfort and vaccine delivery efficiency.

Table 2: Proximate Composition of Cashew Gum

Parameters	Mean ± S. D		95% C. I		P-value
	Raw Cashew Gum	Purified Cashew Gum	Lower	Upper	
Moisture [%]	0.13 ± 0.0093	0.08 ± 0.0078	-0.11541	0.06304	0.117 ns
Total solids [%]	99.87 ± 0.0093	99.92 ± 0.0078	-0.06304	0.15541	0.117 ns
Total ash [%]	0.999 ± 0.1020	0.565 ± 0.0058	-1.3558	0.4872	0.105 ns
Crude fat [%]	3.154 ± 0.1490	6.314 ± 0.2970	0.1790	6.141	0.047*
Crude protein [%]	1.927 ± 0.0209	1.5712 ± 0.0153	-0.5884	-0.1231	0.033*
Nitrogen [%]	0.308 ± 0.0033	0.2514 ± 0.00245	-0.09414	-0.01969	0.033*
Carbohydrate [%]	93.79 ± 0.2390	91.467 ± 0.3140	-5.8710	1.2240	0.076 ns

*- mean differences between groups are statistically significant at 5% significance level [$p \leq 0.05$], ns- mean differences between groups are statistically not significant at 5% significance level [$p \leq 0.05$], C.I- Confidence interval, S.D- Standard deviation

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Table 3: Metal Analysis of Cashew Gum in Different States

Metals	Mean ± SD		95% CI		P-value
	Raw Cashew Gum	Purified Cashew Gum	Lower	Upper	
Lead [Pb]	0.0548 ± 0.0110	0.04495 ± 0.0005	-1.10906	0.08936	0.427 ns
Iron [Fe]	3.1742 ± 0.0744	3.337 ± 0.485	-4.242	4.567	0.721 ns
Zinc [Zn]	0.2522 ± 0.0775	0.2622 ± 0.00177	-0.6864	0.7065	0.885 ns
Calcium [Ca]	4.336 ± 0.526	4.180 ± 1.48	-14.22	13.92	0.913 ns
Manganese [Mg]	23.584 ± 0.134	23.669 ± 0.330	-3.117	3.286	0.794 ns
Sodium [Na]	4.2406 ± 0.0486	5.1068 ± 0.0518	0.2280	1.5044	0.037*
Potassium [K]	8.418 ± 0.417	9.3819 ± 0.0634	-2.826	4.753	0.191 ns

*- mean differences between groups are statistically significant at 5% significance level [p≤0.05], ns- mean differences between groups are statistically not significant at 5% significance level [p≤0.05], C.I- Confidence interval, S.D- Standard deviation

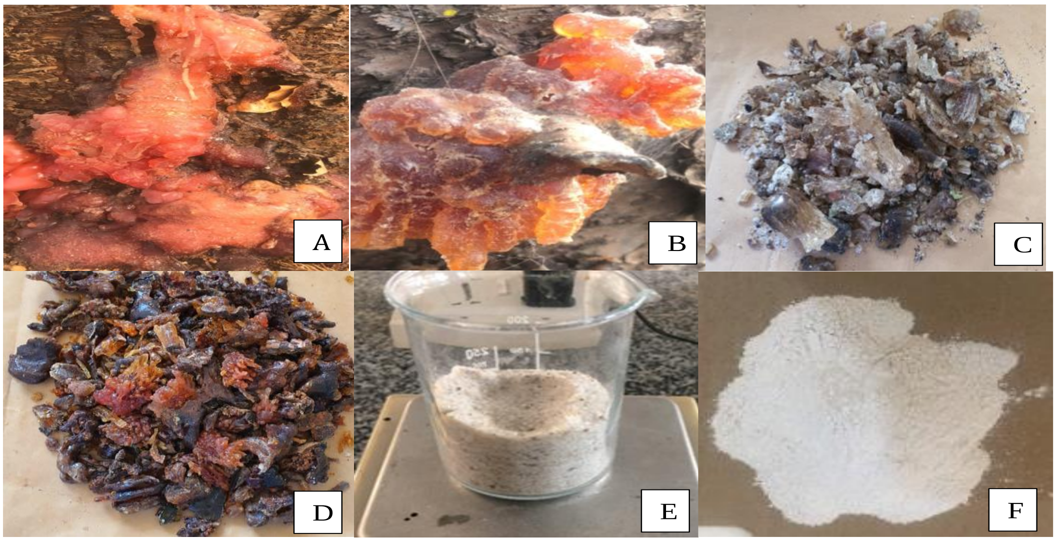

Figure 1: A-F; A-Fresh cashew tree exudate, **B-** Matured cashew tree exudate, **C-** Light grade sorted exudate, **D-** Dark grade sorted exudate, **E-** Milled light grade sorted exudate, **F-** Purified cashew tree gum

Table 4: Phytochemical constituents of cashew gum in different states

Phytochemical	State of Cashew Gum	
	Raw	Purified
Saponins	+	+
Glycosides	+	+
Tannins	+	+
Triterpenoid	+	+
Sterol	_	_
Flavonoid	_	_
Alkaloid	+	+
Coumarins	_	_

-= absent, + = present

Table 5: Swelling Index and pH of Cashew Gum in Different States

Parameter	Mean ± SD		95% CI		P-value
	Raw Cashew Gum	Purified Cashew Gum	Lower	Upper	
Swelling Index	3.20 ± 0.000	1.05 ± 0.070	0.1487	4.1013	0.001*
pH	3.91 ± 0.005	4.08 ± 0.017	3.9001	4.0932	0.001*

*- mean differences between groups are statistically significant at 5% significance level [p≤0.05], ns- mean differences between groups are statistically not significant at 5% significance level [p≤0.05], C.I- Confidence interval, S.D- Standard deviation

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Table 6: Viscosity of Cashew Gum in Different States

State of Gum	Concentration of Gum [Mean ± SD]					P-value
	5%	10%	20%	30%	40%	
Raw	4.00±0.000	3.83±0.764	3.50±0.500	4.83±0.764	14.67±0.288	0.001*
Purified	3.83±0.577	3.17±0.289	2.50±0.500	15.12±0.289	24.50±1.323	

*- mean differences between groups are statistically significant at 5% significance level [p≤0.05], ns- mean differences between groups are statistically not significant at 5% significance level [p≤0.05], S.D- Standard deviation

Conclusion

The assessment of cashew tree gum as a vaccine carrier has shed light on its physical, chemical, and rheological characteristics, along with its safety properties. The purification process resulted in a very pure gum with ideal attributes for vaccine formulation, including low moisture content, high total solids, and consistent mineral composition. Through rheological analysis, the influence of purification on the gum's swelling index, pH levels, and viscosity was evident, showing that the purified gum displayed enhanced stability. Phytochemical analysis revealed the presence of bioactive compounds that may contribute to its immunomodulatory effects and adjuvant properties. Cashew tree gum shows great potential as a novel vaccine carrier material.
Further studies will explore methods to integrate CTG into vaccine formulations, assess its stability, and conduct in vivo studies to evaluate the effectiveness of the formulation. This research seeks to significantly impact veterinary medicine and especially the poultry industry, by providing a natural, biocompatible solution for efficient poultry vaccination, potentially reducing dosages and enhancing accessibility for small-holder farmers while extending its applications to other aspects of animal health to boost local economies.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

References

1. Wang J, Bai Y, Zhu J, Wang X, Liu J. Vaccination in the childhood and awareness of basic public health services program among internal migrants: a nationwide cross-sectional study. BMC Public Health. 2023; 23(1):1257.
2. Fan J, Jin S, Gilmartin L, Toth I, Hussein WM, Stephenson RJ. Advances in infectious disease vaccine adjuvants. Vaccines. 2022; 10(7):1120.
3. Parker EP, Ramani S, Lopman BA, Church JA, Iturriza-Gomara M, Prendergast AJ, Grassly NC. Causes of impaired oral vaccine efficacy in developing countries. Future Microbiol. 2018; 13(1):97-118.
4. Luo X, Song Z, Zeng X, Ye Y, Zheng H, Cai D, Yuan Q, Li H, Tong Y, Lu D, Liu Y. A promising self-nanoemulsifying adjuvant with plant-derived saponin D boosts immune response and exerts an anti-tumor effect. Front Immunol. 2023; 14:1154836.
5. Gao Y and Guo Y. Research progress in the development of natural-product-based mucosal vaccine adjuvants. Front. Immunol. 2023; 14:1152855.
6. Nordin AH, Husna SM, Ahmad Z, Nordin ML, Ilyas RA, Azemi AK, Ismail N, Siti NH, Ngadi N, Azami MS, Mohamad Norpi AS. Natural polymeric composites derived from animals, plants, and microbes for vaccine delivery and adjuvant applications: A Review. Gels. 2023; 9(3):227.
7. Loureiro KC, Jäger A, Pavlova E, Lima-Verde IB, Štěpánek P, Sangenito LS, Santos AL, Chaud MV, Barud HS, Soares MF, Albuquerque-Júnior RL. Cashew gum (*Anacardium occidentale*) as a potential source for the production of tocopherol-loaded nanoparticles: formulation, release profile and cytotoxicity. J Appl Sci. 2021; 11(18):8467.
8. Nandi G and Mukhopadhyay S. Biomedical applications of cashew gum-based micro-and nanostructures. Micro-Nanoengineered Gum-Based Biomater Drug Deliv Biomed Applic. 2022; 1:285-302.
9. Pinto AP, Holanda e Silva KG, Mansur CR. Evaluation of the application of cashew gum as an excipient to produce tablets. Polímeros. 2018; 28:302-308.
10. Silva CN, Di-Medeiros MC, Lião LM, Fernandes KF, Batista KD. Cashew gum polysaccharide nanoparticles grafted with polypropylene glycol as carriers for diclofenac sodium. Materials. 2021; 14(9):2115.
11. Amaral RG, de Andrade LR, Andrade LN, Loureiro KC, Souto EB, Severino P. Cashew gum: A review of Brazilian patents and pharmaceutical applications with a special focus on nanoparticles. Micromachines. 2022; 13(7):1137.
12. Agedah CE, Bawo DD, Nyananyo BL. Identification of antimicrobial properties of cashew, *Anacardium occidentale* L.(Anacardiaceae). J Appl Sci Environ. 2010; 14(3) 12
13. Aqib AI, Atta K, Muneer A, Sohail ML, Rahim K, Hussain F. Natural products as vaccine and different delivery methods. In application of natural products in SARS-CoV-2. Academic Press. 2023. 491-507 p.
14. Gowthamarajan K, Kumar GK, Gaikwad NB, Suresh B. Preliminary study of *Anacardium occidentale* gum as binder in formulation of paracetamol tablets. Carbohydr Polym. 2011; 83(2):506-511.
15. Gyedu-Akoto E, Oduro I, Amoah FM, Oldham JH, Ellis WO, Opoku-Ameyaw K, Hakeem RB. Physico-chemical properties of cashew tree gum. Afr J Food Sci. 2008; 2(5):060-064.
16. Kumar A, Moin A, Ahmed A, G Shivakumar H. Cashew gum a versatile hydrophyllic polymer: a review. Curr Drug Ther. 2012; 7(1):2-12.
17. Ofori-Kwakye K, Asantewaa Y, Kipo SL. Physicochemical and binding properties of cashew tree gum in metronidazole tablet formulations. Int J Pharm Pharm Sci. 2010; 2(4):105-109.
18. Kumar R, Patil MB, Patil SR, Paschapur MS. Evaluation of *Anacardium occidentale* gum as gelling agent in aceclofenac gel. Int J Pharmtech Res. 2009; 1(3):695-704.
19. Mali YN, Pawar SP, Gujarathi NA, Rane BR, Bakliwal SR. Applications of natural polymers in sustained release drug delivery system: a review. Pharm Sci Monit. 2012; 3(4) 19.
20. Nayak AK, Ansari MT, Sami F, Bera H, Hasnain MS. Cashew gum in drug delivery applications. In Natural polysaccharides in drug delivery and biomedical applications. Academic Press. 2019. 263-283 p.
21. Carvalho NS, Silva MM, Silva RO, Nicolau LA, Sousa FB, Damasceno SR, Silva DA, Barbosa AL, Leite JR, Medeiros JV. Gastroprotective properties of cashew gum, a complex heteropolysaccharide of *Anacardium occidentale*, in naproxen-induced gastrointestinal damage in rats. Drug Dev Res. 2015; 76(3):143-151.

 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

22. Habib A, Anjum KM, Iqbal R, Jaffar G, Ashraf Z, Khalid MS, Taj MU, Zainab SW, Umair M, Zohaib M, Khalid T. Vaccine adjuvants: Selection criteria, mechanism of action associated with immune responses and future directions. Iran J Immunol. 2023; 20(1):1-5.
23. Castrodeza-Sanz J, Sanz-Muñoz I, Eiros JM. Adjuvants for COVID-19 vaccines. Vaccines. 2023; 11(5):902.
24. Banu KS and Cathrine L. General techniques involved in phytochemical analysis. Int J Adv Res Chem Sci. 2015; 2(4):25-32.
25. AOAC. Official Methods of Analysis, 15th Ed., Association of Official Analytical Chemists, Inc., Arlington, VA. 1990.
26. Stoykov M, Milkov M, Peev S. Biocompatibility of materials and products used in medicine and dental medicine. Int Bull Otorhino. 2022; 18(1):27-38.
27. Goñi-de-Cerio F, Mariani V, Cohen D, Madi L, Thevenot J, Oliveira H, Uboldi C, Giudetti G, Coradeghini R, Garanger E, Rossi F. Biocompatibility study of two diblock copolymeric nanoparticles for biomedical applications by in vitro toxicity testing. J Nanoparticle Res. 2013; 15:1-7.
28. Francis G, Kerem Z, Makkar HP, Becker K. The biological action of saponins in animal systems: a review. Br J Nutr. 2002; 88(6):587-605.
29. A Ribeiro K, V Chaves H, Pereira Filho M, Ribeiro Pinto I, Andressa Martins Monteiro D, Oliveira Matos S, Santi-Gadelha T, Alberto de Almeida Gadelha C, Thalles Jocelino Gomes de Lacerda J, MV Aguiar L, MA Pereira K. lpha-2 Adrenergic and Opioids Receptors Participation in Mice Gastroprotection of *Abelmoschus esculentus* Lectin. Curr Pharm Des. 2016; 22(30):4736-4742.
30. Asuk AA, Agiang MA, Dasofunjo K, Willie AJ. The biomedical significance of the phytochemical, proximate and mineral compositions of the leaf, stem bark and root of *Jatropha curcas*. Asian Pac J Trop Biomed. 2015; 5(8):650-657.
31. Orji EA, Ejere VC, Orji CT, Anorue EC, Ossai NI, Ojua EO, Eyo JE. Phytochemical Profiling and GC- MS Analysis of *Lantana camara* Leaf Extract. Trop J Nat Prod Res. 2024; 8(7): 7920-7927.
32. Ojewumi WA and Sanusi OJF. Evaluation of Proximate, Mineral, Anti-Nutrients and Phytochemical Constituents of Indigenous Beans (*Cajanus cajan*, *Sphenostylis stenocarpa* and *Phaseolus lunatus*). Trop J Nat Prod Res. 2020; 4 (10) 32
33. Nnadiukwu UC, Onyeike EN, Ikewuchi CC, Patrick-Iwuanyanwu KC. Phytochemical and nutrient composition of rice husks: Trop J Nat Prod Res. 2023; 7(2):2457-2463.
34. Ojewumi WA and Sanusi OJF. Evaluation of Proximate, Mineral, Anti-Nutrients and Phytochemical Constituents of Indigenous Beans (*Cajanus cajan, Sphenostylis stenocarpa* and *Phaseolus lunatus*). Trop J Nat Prod Res. 2020; 4(10) 34
35. Nnadiukwu UC, Onyeike EN, Ikewuchi CC, Patrick-Iwuanyanwu KC. Phytochemical and nutrient composition of rice husks: Trop J Nat Prod Res. 2023; 7(2):2457-2463.