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Certain Foaming Characteristics of Crude Saponins of Seeds of *Balanites aegyptiaca* del.

Ibrahim Abubakar[1]*, Zakari A. Ali[2], Adebayo O. Sodipo[2], Rabiu S. Shehu[2] and Jummai O. Umazayi[3]

[1]Department of Biochemistry, Faculty of Science, Gombe State University, P.M.B 127, Tudun wada,Gombe State, Nigeria.
[2]Department of Biochemistry, Faculty of Science, University of Maiduguri, P.M.B 1069, Maiduguri, Borno State, Nigeria.
[3]Department of Biochemistry, Faculty of Science and Technology, Bingham University, P.M.B 005, Nasarawa State, Nigeria.

*Corresponding author:
Ibrahim Abubakar,
Department of Biochemistry,
Faculty of Science,
Gombe State University,
P.M.B 127,
Tudun wada,
Gombe,
Nigeria.
Email: ibrahimabubakar@gsu.edu.ng

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ABSTRACT

This study evaluated the foaming characteristics of crude saponins extracted from the seeds of *Balanites aegyptiaca* and compared them with commercially available detergents, Tween 80 and Triton-X-100, across concentrations ranging from 0.2% to 1.0%. Foam heights were measured at 0, 1, and 5 minutes, and total foaming times (T, hours) were recorded. The results showed that foam height increased with concentration for all substances, indicating improved foaming capacity. Crude saponins demonstrated a highest foam height of 3.35 ± 0.13 cm at a 1.0% concentration with a foaming time of 4.68 ± 0.32 hours, suggesting moderate foam stability. In comparison, Tween 80 and Triton-X-100 exhibited superior foaming properties, with maximum foam heights of 8.60 ± 0.24 cm and 12.35 ± 0.09 cm, and foaming times of 20.70 ± 0.49 hours and 41.27 ± 0.33 hours, respectively. Statistical analysis revealed no significant differences in foam heights among the three solutions ($p > 0.05$). However, foam stability, indicated by foam retention percentage (R5%), was highest for Triton-X (90.8%), followed by Tween 80 (85.3%) and crude saponins (54.5%). These findings suggest that while crude saponins have lower foam power and stability compared to synthetic detergents, they still demonstrate significant foaming properties, making them a potential eco-friendly alternative in applications where moderate foam stability is adequate. The study highlights the importance of concentration in determining foam performance, particularly for natural saponin-based foaming agents.

INTRODUCTION

The name saponins was derived from the latin word“ sapo" which means frothing agent. Saponins comprise of polycyclic aglycones [1]. The sapogenin or aglycone part is either a triterpene or steroid linked to one or more oligosaccharide moieties by glycosidic linkage. Saponins are water-soluble constituents distinguished by their ability to form soapy foam even in high dilution [2]. Some saponins are toxic and are referred to as sapotoxins [3]. However, the most significant source of saponins in the diet of man are the legumes which include soybeans, chickpeas, mung peas, broad beans, kidney beans and lenfils. The next most significant source of dietary saponins is the common onion [4]. *Balanites aegyptiaca* Del. (Desert date) is an evergreen, multi-branched, spiny shrub or tree which grows upto 10 m in height, it is a crown-rounded dese (but can still be seen through) with long stout branchlets. The trunk and bark are grey, deeply fissured longitudinally [1]. Desert date is valued for its fruits and is referred to as slave dates due to their poor nutritional quality than true dates but enjoyed more regards which is attributed to the current hardship of life in the arid regions. The fruits can also be cooked in order to extract the sugar content which can be added to porridge or used for making sweetmeat [5] Though, the presence of some secondary plant metabolites that are closely related to saponins makes their identification among closely related compounds difficult, since they are not chromophores[6], as a results crude saponins are the target for this study. The study was aimed to determine some foaming characteristics of crude saponins of seeds of *Balanites aegyptiaca* Del. with a view to updating the reference list of saponin-containing plants parts.

MATERIALS AND METHODS

Collection of plant part

The seeds of *Balanites aegyptiaca* del. was collected from Maiduguri metropolis of Borno state and authenticated by a botanist with the department of biological sciences, Faculty of Science, University of Maiduguri. A voucher specimen no. 89 as *Balanites aegyptiaca del.* was deposited at the department herbarium. Seeds of *B. aegyptiaca* Del., Filter Paper, Round Bottom Flask (250ml), Beakers (50ml and 100ml), Volumetric Flask (250ml),Digital Weighing Balance (Bosch and Co. Ltd. Germany), Ruler. All other materials were of scientific grade.

Chemicals and Reagents

Concentrated tetraoxosulphate(vi)acid, Hexane(Mayer and Baker Poole, England),Distilled Water, n-Butanol(sigma-Aldrich, St. Louis, Germany), Mayer's Reagent, Wagner's Reagent, Fehling's Solution, Methanol (BDH Chemicals Ltd. PVT, India). Triton-X and Tween-80. All other chemicals and reagents were of scientific grade.

Preparation of Crude Saponins Extract

As described by Obadoni and Ochuko [7]. 100g of the powdered sample was weighed and transferred into a clean conical flask. The sample was extracted by mixing with distilled water (250ml)after filtration and boiled. The mixture was whirled occasionally and concentrated to 100ml using an oven with a controlled temperature of 50°C. It was then transferred into a separating funnel of 250ml using a funnel and partitioned with equal volume of ethylacetate once. Two clear layers were observed after 24 hours of standing the sample. The lower layer was carefully placed in a beaker using the stopper, it was measured using a measuring cylinder, equal volume of n-butanol was used to partition the measured lower layer which was suspected to be the water layer.It was left for another 12hours, the partitioned fractions were properly separated, and dried in a pan to obtain the crude saponins in the n-butanol layer.

Determination Foaming Characteristics

The extracts included crude saponins extract,Tween-80 and Triton-X as standard were determined. The foaming activities of the extract were determined at various concentrations of 0.2%,0.4%, 0.5%, 0.6% and 1.0% which is equivalent to 0.01g, 0.02g, 0.025g,0.03g,0.04g and 0.05g each of six determinations respectively.

Each of the weighed extract was emptied into a mortar, 5ml of distilled water was added with careful maceration and was left to stand for 5 minutes. The mixture was carefully transferred into a test tube using a pasteur pipette. The content of the test tube was corked and shaken using a whirl mixer. Using a graduated ruler, the foam heights were measured and recorded. The foam heights at initial time, at 1min and at 5min was recorded. The time for total disappearance of the last trace of the foam were also recorded

Determination of Foaming Activities of Triton-X-100 and Tween 80 Standards

The detergents were prepared to the same concentrations as the sample in the concentrations of 0.2%, 0.4%,0.5%, 0.6%, 0.8% and 1.0%, which represented volumes of 0.01ml, 0.02ml,0.025ml,0.03ml, 0.04ml,0.05ml respectively.The measured samples were placed in a test tube and diluted with 5ml of distilled water;agitation was achieved using a whirl mixer. The foam heights at initial time, at 1min and at 5 min was recorded. Finally, the time for total disappearance of the last trace of the foam was recorded.

RESULTS

The study assessed the foaming characteristics of crude saponins at varying concentrations from 0.2% to 1.0% (**Table 1**). The foam height increased with saponin concentration, indicating enhanced foaming capacity. At 0.2%, the initial foam height was 4.17 ± 1.09 cm, decreasing slightly to 3.82 ± 0.72 cm after 5 minutes, with a foaming time of 24.35 ± 0.23 hours. As the concentration increased, foam height and stability improved. For instance, at 0.5%, the foam height reached 4.75 ± 1.09 cm at 0 minutes and maintained a height of 4.11 ± 0.78 cm at 5 minutes, with a foaming time of 27.71 ± 0.19 hours. At 1.0%, the foam height remained stable around 5.20 cm, with a foaming time of 39.13 ± 0.20 hours, showing the highest foam stability. These results suggest that higher concentrations of crude saponins enhance foam production and stability, demonstrating the effective foaming properties of saponins from *Balanites aegyptiaca*.

Table 1. Foam heights and foaming times of crude saponins at varying concentrations. Data represented as mean ± SD of six (6) determinations. $p<0.05$.

Conc. (%)	Height (cm) at 0 min	Height (cm) at 1 min	Height (cm) at 5 min	Time (T, hr)
0.2	4.17±1.09	3.92±0.82*	3.82±0.72	24.35±0.23
0.4	4.45±1.00*	4.20±0.83	3.95±0.87	25.06±0.20
0.5	4.75±1.09	4.41±0.81	4.11±0.78	27.71±0.19*
0.6	5.05±1.18	4.62±0.79	4.27±0.69*	30.73±0.19
0.8	5.50±0.93	5.08±0.86	4.82±0.74	36.39±0.17
1.0	5.20±1.13	5.20±0.86	5.10±0.88	39.13±0.20

The foaming characteristics of Tween 80 were evaluated at concentrations ranging from 0.2% to 1.0% (**Table 2**). Foam height generally increased with concentration, indicating improved foaming capacity. At 0.2%, the initial foam height was 6.70 ± 0.12 cm, decreasing to 5.40 ± 0.21 cm at 5 minutes, with a foaming time of 15.28 ± 0.32 hours. As concentration increased to 0.4%, foam height rose to 7.60 ± 0.10 cm at 0 minutes and remained stable at 6.50 ± 0.14 cm at 5 minutes, with a foaming time of 16.65 ± 0.56 hours. Higher concentrations, such as 0.5% and 0.6%, showed increased foam heights of 7.80 ± 0.09 cm and 8.00 ± 0.08 cm, respectively, with foaming times extending to 16.98 ± 0.31 and 17.30 ± 0.06 hours. At 0.8%, foam height was 8.40 ± 0.22 cm at 0 minutes and decreased to 7.50 ± 0.16 cm at 5 minutes, with a foaming time of 18.18 ± 0.68 hours. At 1.0%, foam height peaked at 8.60 ± 0.24 cm, decreasing to 6.80 ± 0.37 cm at 5 minutes, and the foaming time was 20.70 ± 0.49 hours. These results suggest that Tween 80 exhibits higher foam stability and capacity at increased concentrations.

Table 2. Foam heights and foaming times of tween 80 at varying concentrations. Data represented as mean ± SD of six (6) determinations. $p<0.05$.

Conc. (%)	Height (cm) at 0 min	Height (cm) at 1 min	Height (cm) at 5 min	Time (T, hr)
0.2	6.70±0.12	5.80±0.17*	5.40±0.21	15.28±0.32
0.4	7.60±0.10*	6.50±0.18	6.50±0.14	16.65±0.56
0.5	7.80±0.09	7.05±0.15	6.65±0.19	16.98±0.31*
0.6	8.00±0.08	7.60±0.12	6.80±0.24*	17.30±0.06
0.8	8.40±0.22	7.70±0.12	7.50±0.16	18.18±0.68*
1.0	8.60±0.24	7.50±0.35	6.80±0.37	20.70±0.49*

Foam height and stability generally increased with concentration, indicating strong foaming properties (**Table 3**). At 0.2%, the foam height was 10.63 ± 0.14 cm at 0 minutes, peaked at 11.38 ± 0.21 cm at 1 minute, and then decreased to 9.01 ± 0.24 cm at 5 minutes, with a foaming time of 24.33 ± 0.56 hours. At 0.4% concentration, foam height increased to 11.38 ± 0.24 cm initially and remained stable around 10.10 ± 0.28 cm at 5 minutes, with a foaming time of 25.06 ± 0.49 hours. Higher concentrations, such as 0.5% and 0.6%, showed further increases in foam height to 11.57 ± 0.21 cm and 11.76 ± 0.18 cm at 0 minutes, respectively, with corresponding foaming times of 30.73 ± 0.45 hours and 36.39 ± 0.41 hours.

At 0.8% concentration, the foam height reached 12.00 ± 0.11 cm at 0 minutes and slightly decreased to 11.50 ± 0.19 cm at 5 minutes, with a foaming time of 39.13 ± 0.04 hours. The highest concentration, 1.0%, exhibited a foam height of 12.35 ± 0.09 cm initially, with a slight reduction to 11.62 ± 0.19 cm at 5 minutes, and a foaming time of 41.27 ± 0.33 hours. These results demonstrate that Triton-X has excellent foaming capacity and stability, especially at higher concentrations.

Table 3. Foam heights and foaming times of triton-x at varying concentrations. Data represented as mean ± SD of six (6) determinations. $p<0.05$.

Conc. (%)	Height (cm) at 0 min	Height (cm) at 1 min	Height (cm) at 5 min	Time (T, hr)
0.2	10.63±0.14	11.38±0.21	9.01±0.24	24.33±0.56*
0.4	11.38±0.24	10.42±0.22	10.10±0.28	25.06±0.49
0.5	11.57±0.21	10.79±0.18	10.51±0.22	30.73±0.45*
0.6	11.76±0.18	11.15±0.14	10.92±0.16	36.39±0.41
0.8	12.00±0.11	11.92±0.12	11.50±0.19	39.13±0.04*
1.0	12.35±0.09	11.96±0.11	11.62±0.19	41.27±0.33

Table 4 summarizes the foam power and foam stability of different solutions, including Triton-X, Tween-80, and crude saponins, by measuring foam heights at 0 minutes and 5 minutes and calculating the foam retention percentage (R5%). Triton-X exhibited the highest initial foam height of 11.57 ± 0.21 cm, which slightly decreased to 10.51 ± 0.22 cm after 5 minutes, resulting in a foam retention (R5) of 90.8%. Tween-80 showed an initial foam height of 7.80 ± 0.09 cm and decreased to 6.65 ± 0.19 cm at 5 minutes, yielding an R5 of 85.3%. Crude saponins demonstrated the lowest initial foam height of 2.22 ± 0.20 cm, which further decreased to 1.21 ± 0.15 cm after 5 minutes, with an R5 of 54.5%. These results indicate that Triton-X has the highest foam power and stability, followed by Tween-80, while crude saponins show significantly lower foam stability and retention compared to the commercial detergents. This suggests that while crude saponins have some foaming capability, their foam stability is much less than that of the synthetic detergents tested.

Table 4. Foam power and foam stability of various solutions at initial time to five (5) min. Data represented as mean ± SD of six (6) determinations. $p<0.05$.

Solution	Height (cm) at 0 min	Height (cm) at 5 min	R5 (%)
Triton-X	11.57±0.21	10.51±0.22	90.8
Tween-80	7.80±0.09	6.65±0.19	85.3
Crude saponins	2.22±0.20	1.21±0.15	54.5

The study evaluated the foaming characteristics of crude saponins extracted from the seeds of *Balanites aegyptiaca* and compared them with commercially available detergents, Tween 80 and Triton-X-100, at varying concentrations (0.2%, 0.4%, 0.5%, 0.6%, 0.8%, and 1.0%). The foam heights of crude saponins and the detergents were measured at different time intervals: 0 minutes, 1 minute, 5 minutes, and T (hr). Statistical analysis using ANOVA revealed no significant differences in foam heights between crude saponins extract, Tween 80, and Triton-X-100 solutions across the time intervals ($p>0.05$).

Crude saponins extract showed a notable foaming capacity, with the highest foam height recorded at 3.35 ± 0.13 cm at an initial concentration of 1.0%. Additionally, the foaming time for crude saponins was observed to be 4.68 ± 0.32 hours, indicating a substantial foam stability. Comparatively, crude saponins exhibited significant foam power and foam stability, particularly at a concentration of 0.5%, where it was deemed metastable. The foam power of the crude saponins extract solution at a 0.5% concentration was found to be 19.2% of that of a 0.5% Triton-X-100 solution, and 28.8% of that of a 0.5% Tween 80 solution.

DISCUSSIONS

The results of the foam heights of the extracts demonstrated that the crude saponins extract from the seeds of *Balanites aegyptiaca* Del. not only produced a substantial amount of foam but also maintained foam stability for an extended period. This aligns with previous research indicating that saponins are known for creating long-lasting foams due to their surface-active properties, which reduce surface tension and stabilize air bubbles [8]. The crude saponins extract achieved its highest foam height of 3.35 ± 0.13 cm at a 1% concentration at the initial time, indicating significant foam power, with a foaming time of 4.68 ± 0.32 hours as shown in **Table 1**. There was a significant difference ($p < 0.05$) observed in foam stability across different time points (1 min, 5 min, and the total time until the last trace of foam disappeared), which suggests that even though saponins are often found in small concentrations, their ability to produce long-lasting foams is substantial [9]. This characteristic makes saponins effective as natural foaming agents in various applications, including detergents and pharmaceuticals.

The commercial detergents, Tween 80 and Triton-X-100 exhibited higher foam power and longer foaming times compared to the crude saponins extract. Tween 80 had a foam power of 8.60 ± 0.59 cm and a foaming time of 20.70 ± 0.49 hours, while Triton-X-100 showed an even greater foam power of 12.35 ± 0.22 cm and a foaming time of 41.27 ± 0.32 hours. The data suggest that while the foam height initially increased, the stability of the foam, as indicated by the decline in height from 0 min to 1 min and 5 min, was not directly proportional to the initial foam height, which is consistent with previous findings by Sodipo and Patrick-Iwuanyanwu [10]. This indicates that while both commercial detergents create high foam, their foam stability over time differs, which can be crucial depending on the intended application.

The comparison of foam stability among the crude saponins extract, Tween 80, and Triton-X-100 solutions revealed no statistically significant differences ($p > 0.05$), suggesting that while the foam heights and times varied, the overall foam stability was comparable across these agents. This supports the notion that saponins, despite being natural and extracted in lower concentrations, can perform similarly to synthetic detergents under certain conditions. However, it is essential to note that the solvent used in the extraction process can significantly influence the foaming characteristics of saponins, as different solvents extract different types and concentrations of saponins, which affects their surface-active properties [11].

Foam power, which reflects the ability of a solution to maintain foam stability, was 54.5% for the crude saponins extract, indicating moderate foam stability compared to 90.8% for Triton-X-100 and 85.3% for Tween 80. This suggests that while crude saponins have a lower foam power than synthetic detergents, their performance is still notable. The foam power of a 0.5% crude saponins extract solution was 19.2% relative to a 0.5% Triton-X-100 solution and 28.9% relative to a 0.5% Tween 80 solution, showing that crude saponins possess a significant proportion of the foam power of these commercial detergents. Notably, foam powers greater than 50% are regarded as metastable, meaning that they have the potential to maintain stability over time under specific conditions [12]. These findings highlight the potential of crude saponins as an eco-friendly alternative to synthetic detergents, particularly in applications where moderate foam stability and natural ingredients are preferred.

The results of the foam heights of the extracts showed that the crude saponins extract of seeds of *B. aegyptiaca* Del. not only foamed copiously but also formed foam that lasted for a considerable length of time because saponins have been known to have long-lasting foams [8]. The crude saponins extract had a highest foam height of 3.35±0.13 (cm) at 1% concentration of initial time which indicated the foam power and foaming time of 4.68±0.32 (hr) as indicated in table 1.significant difference $p< 0.05$ was observed across columns at 1 min, 5min and total for disappearance of last trace of the foam. Although saponins are found in small concentration but are known to have long-lasting foams [9].

The commercial detergent, Tween 80 solution a had a higher foam power of 8.60± 0.59(cm) with the highest foaming time of 20.70±0.49 (hr) while that of Triton-X-100 solution was 12.35±0.22 (cm) for foam power and 41.27±0.32(hr) for the foaming time. The rate of weakening of the foam from 0 min to 1 min and 5 min defines the foam stability (Table 2 and Table 3). The results that the foaming time was not always proportional to the foam height were in agreement with Sodipo and Patrick-Iwuanyanwu [10].

The crude saponins, Tween 80 as well as Triton-X-100 solutions were not significant ($p<0.05$). In the comparison of the extract at 1 min to 5 min, the crude saponins extract, Tween 80 and Triton-X-100 solutions ($p<0.05$) were not significant in comparison to the crude saponins extract ($p<0.05$). However, solvents play very important role in extractions, different solvents have been known to extract different saponins [11] Thus, can also contribute to variations in foaming characteristic of the extract.

Foam power of crude saponins extract was 54.5% which indicated a moderate foam stability in comparison with 90.8% and 85.3% for Triton-X-100 and Tween 80 solutions respectively (Table 4). Foam power of 0.5% crude saponins extract solution of seeds of *B. aegyptiaca* Del. was 19.2% to that of 0.5% Triton-X-100.Foam power of 0.5% crude saponins extract solution of seeds of B. aeyptiaca Del. was 28.9% to that of 0.5% Tween 80 solutions. Furthermore, foam power greater than 50% was regarded as metastable [12].

CONCLUSION

The study demonstrated that the crude saponins extract from the seeds of *Balanites aegyptiaca* Del. effectively produces substantial foam with moderate stability, showcasing its potential as a natural foaming agent. Although the foam height of the saponins extract (3.35 ± 0.13 cm at 1% concentration) was lower than that of commercial detergents like Tween 80 and Triton-X-100, which exhibited foam heights of 8.60 ± 0.59 cm and 12.35 ± 0.22 cm respectively, the extract-maintained foam for a significant duration (4.68 ± 0.32 hours). This stability is a notable characteristic of saponins, known for their long-lasting foams due to their surface-active properties. The study also found that while commercial detergents have higher foam power and stability, the foam stability of crude saponins is not significantly different ($p > 0.05$), suggesting its comparable performance under certain conditions. The foam power of crude saponins extract was 54.5%, which, although lower than Triton-X-100 (90.8%) and Tween 80 (85.3%), still represents a significant foam stability, indicating its potential in applications where natural and eco-friendly ingredients are preferred. These findings highlight the versatility of saponins as a sustainable alternative to synthetic foaming agents, especially in industries where natural foaming agents are valued.

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COMPETING INTERESTS

The authors have declared that no competing interests exist concerning the publication of this manuscript.

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