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Original Article

Using Biosurfactants from Plants to Treat Chicken Feathers into a Green Oil Absorbent Material

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Abstract: Though light as a feather, with the vast quantities of chickens produced annually, the number of feathers produced is considerable. Research has shown that the feathers have hydrophobic properties and can therefore be used to make products that absorb oil. However, the use of large amounts of toxic detergents to clean chicken feathers in reported studies has reduced the environmental significance of agricultural waste reuse. In this study, we evaluated the possibility of replacing toxic cleaning agents with eco-friendly natural cleaners in the handling of chicken feathers. Water-based extracts of soapnuts and bo-ket fruits have been selected for our study due to their high saponin content - an effective cleaning agent, and have been used as a dishwashing liquid or shampoo for a long-time by local housewives. Our study showed that natural detergents derived from soapnuts have been shown the ability to remove lards on the plastic surface, and to clean chicken feathers, thereby increasing their capacity to absorb various oils including cooking oil, used cooking oil, and lubricant oil. We have also created an oil-absorbing pillow containing soapnut extract-treated chicken feathers with a maximum efficiency of 16.8 g/g in absorbing lubricant oil. Our research opens new avenues for the use and treatment of poultry feathers, contributing to the reduction of solid waste from the poultry industry by methods which is friendlier to the environment. The greenness of the created absorber is guaranteed.

Keywords: Plant extracts, chicken feathers, oil absorbent, natural detergent.

1. Introduction

Poultry production in Vietnam has made great leaps and bounds. The number of farms and poultry farms also increased strongly. According to the National Center for Agricultural Extension, there are currently about 11,000 poultry farms nationwide. Accompanying this development, waste from the poultry industry is considerable. Specifically, with more than 400 million broilers produced each year, 0.5 to 1 million pounds of feathers are generated.

Poultry feathers have been believed to hold several good and reusable properties which can be used to produce a variety of valuable products. Research has shown that keratin (a protein) in feathers can be used to produce a

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variety of valuable products such as pillows, diapers, insulation, plastics, mattress covers, etc. [1]. Indeed, feathers can be ground into powder and added to poultry feed as a source of protein. In addition, the ability of poultry feathers to absorb oil waste has been reported associated with their porous and hydrophobic characteristics [2]. However, the feathers need to be treated with alkaline or strong detergent to wash out grease and other impurities on the surface [2, 3]. Untreated waste poultry feathers exhibited a slow sorption rate for oil. Even though called green materials, oil-absorbent from feathers were treated with numerous chemicals before use. In this study, we have an effort to use bio-surfactant extracted naturally from plants alternative for chemicals in treating poultry feathers. This study targets to generate natural and completely friendly environmental oil-absorbent material.

2. Experimental

2.1. Preparation of Detergent Solution

Soapnut extract

100 g of well-dried pericarp shell of local soapnuts (*Sapindus mukorossi*) was soaked into 1L of water overnight. On the next day, the mixture was boiled for over 25 mins. Filter to remove residue, the clear liquid obtained is a cleaning solution from soapnuts.

Fermented soapnut solution

The fermented soapnut solution was bought from Tipihandmade company, which specializes in supplying and manufacturing soapnut-based cleaning solutions. Briefly, the mixture of 1 kg of dried soapnut pericarp shell, 1 kg of white sugar, 1 pineapple and 10 L of water was put in a covered container. The solution has been going to appear foam for about the first month, then continue to incubate for another 2 months to get soapy water. After around 3 months, a thick layer of yeast biomass will appear on the surface of the solution, The mixture was then filtered and bottled for long-time storage.

Bo-ket fruit extract

100 g of cleaned and dried fruits of bo-ket (*Gleditsia fera (Lour.) Merr.*) was grilled until fragrant, and then boiled in 1 L of water for about 20 minutes. The mixture was allowed to settle and decant the upper clear water.

Commercial detergent solution

To compare the cleaning efficiency of natural detergents, we used control of commercial dishwashing liquid commonly used in Vietnam. Calculating the surfactant concentration equivalent to that in the natural extract will give better comparative efficiency. According to previous studies, the saponin extract from the mixture of 1:10 of soapnut pericarp and water ranges from 0.3-0.4 wt% [4, 5]. The surfactant content in concentrated dishwashing liquid is usually around 30-40 wt%, so we diluted 10 g of concentrated dishwashing liquid into 1 L of water to get a surfactant concentration in the range of 0.3-0.4 wt%.

2.2. The Effectiveness of the Detergent

Evaluation of foam strength and stability

50 mL of cleaning solution was stirred on a magnetic stirrer at 800 rpm, for 1 min. After stopping stirring for 2 min to stabilize the foam in the solution, the volume of foam in the column was recorded at different time points.

Cleaning action of detergent

To demonstrate the cleaning ability of bio-detergents, the method was used with little modification. 1.5 g of lard was applied to a polypropylene dish, and left to dry for 5-6 hours. The plastic dishes have measured the weight before washing. Then, the larded dish was washed twice for 7 mins or three times for 10 mins. Every 10 ml of different detergents was used and then allowed dishes to dry. The weight of the washed dish was observed as weight after washing. The amount of lard removed is calculated based on the difference in the weight of the same dried plastic dish before and after washing.

2.3. Treatment of Chicken Feathers

Freshly plucked wet untreated chicken feathers were washed 5 times with water before deeply cleaned with various detergents.

Untreated waste chicken feathers (5 g) feather samples were placed in a beaker to which was added different detergent solutions at a liquid to solid ratio of 40:1. The sample was agitated continuously for 10 mins to remove the grease and other contaminants. The treated feathers were rinsed again in distilled water 3 times and then laid on glasses and dried to a constant mass at around 90 - 100 °C in an air-forced dryer.

2.4. Oil Absorption Capacity of Chicken Feather

To evaluate the efficiency of the chicken feather in absorbing oil, we stuffed a definite amount of treated chicken feathers into 6.5x7.5 cm non-woven bags and then sealed to make the oil absorbent pillow. The cover bags of the pillows are made from a non-woven thin layer of polypropylene which are waterproof, so allows oil to pass through and contact with chicken feathers inside. The oil-absorbing capacity of these cover bags was also measured to eliminate their influence on the proving of the oil-absorbing ability of chicken feathers.

The oil absorbent pillow containing 1 g each of treated whole chicken feathers was dispersed in a beaker containing 100 ml water and 50 ml of various oils including cooking oil (sunflower oil), used cooking oil from restaurants and lubricant oil [2, 3]. The oil absorption experiments were carried out at room temperature for 1 min. The pillows were then picked up with forceps and allowed to drain for 2 mins until oil began to slowly stop dripping from the pillows. The weight of the pillow was recorded (Final weight) and the amount of oil absorbed per unit mass was calculated based on equation (1):

$$\text{Oil recovered per unit mass of sorbent} = \frac{\text{final weight of bag} - \text{initial weight}}{\text{initial weight}} \quad (1)$$

2.5. Statistics Analysis

To validate and verify the results, SPSS software was used for statistical analysis. Two-way Anova was employed to assess the effect of treated solutions and the kind of oil on the absorbent capacity of treated chicken feathers. All measurements described with mean ± S.D were from at least three replicates.

3. Results and discussion

3.1. Bio-detergent Evaluation

3.1.1. The Foaming Capacity

The cleaning power is not from foam itself, but foam keep detergents stay longer on the surface. Therefore, it allows the cleaning agents to penetrate into dirties and remove them better. For this, one of the properties of detergents often evaluated is their ability to create and hold foam. The results in Figure 1 show that both fermented and non-fermented soapnut extracts have better foaming capacity than either commercial dishwashing liquid and bo-ket fruit extract solution. And the foam stability of the soapnut extract is much longer. This is related to the presence of saponins in the soapnut and bo-ket fruit extract [6, 7]. In the case of fermented soapnuts extract, foaming can also be caused by substances produced by microorganisms.

In the section of materials and methods, we have mentioned the calculation of saponin concentration in the extract based on previous studies. This is a basis for the preparation of other cleaning solutions with comparable concentration of surfactants. The foam properties of soapnut extract in Figure 2 are completely consistent with the foam behavior of solutions containing 0.3 to 0.4 wt% purified saponin as illustrated in the study by Nurudeen Yekeen et al., 2020 [7].

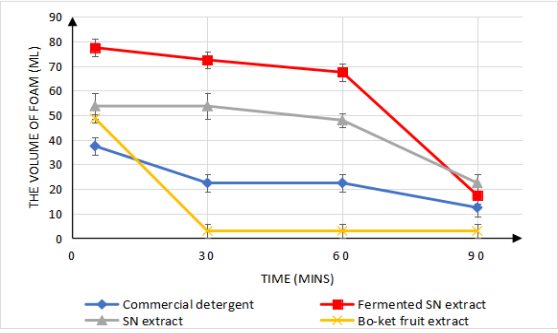

Figure 1. Evaluation of foam strength and stability of natural detergents in the comparison to commercial dishwashing liquid. SN: soapnut extract.

This result once again confirms the correction of our calculation, with the saponin concentration in the soapnut extract falling in the range of 0.3-0.4 wt%.

3.1.2. The Cleaning Effectiveness of Bio-detergent

The ability to make foam is not an important factor in proving the cleaning action of a detergent, but sometimes just creating a feeling for consumers. In the next experiment, we have investigated the ability to remove grease of natural detergent on high-adhesive surfaces such as polypropylene plastic. 1.5 g of lard was applied to polypropylene dishes and allowed to dry naturally for 6 hours before being soaked and washed with various detergents. The difference between the weights of the plate before and after being washed was used to determine the amount of lard that was removed by the detergents.

The results in Figure 2 illustrated the degreasing capacity of fermented and non-fermented soapnuts extracts compared with bo-ket fruit extracts. Interestingly, the cleaning ability of the non-fermented soapnuts extract was much more effective (0.70±0.14 g) than that of the fermented ones (0.25±0.07 g). This can be explained by the microbial activity present on the surface of soapnuts that degraded saponins during the fermentation process [8]. Our studies have gone against the habit of using fermented soapnut water (preparing for 1 month) of Vietnamese housewives in terms of cleaning efficiency compared to fast soapnut extract (preparing for 1 day). Even so, more thorough studies on the safety of soapnut extract are needed before it can be popularized as a daily cleaning product. Some saponins can form insoluble complexes with cholesterol membranes and thus form permeable holes in the red blood cell membranes, causing membrane lysis and loss of hemoglobin in animals [9-11]. Studies have shown that some saponins can be toxic to insects and cold-blooded animals [12]. Soapnut fruit extract was also lethal to glasshouse whitefly at a concentration of 88 ppm [13]. Fermentation of soapnut extracts probably convert a toxic form of saponin to a less toxic one [11].

In this study, we have investigated to use of natural detergent to replace toxic ones such as Sodium dodecyl sulfate (SDS) which was used in other studies [3] in removing grease from chicken feathers. These grease stick to only a very small amount on the feathers due to the oil glands on the rump of the chicken and the slaughtering operation. Although, the cleaning activity of soapnut extracts is incomparable to commercial dishwashing liquid, with the amount of grease removed being around 1/2 of the amount removed by the commercial product (Fig. 2), SEM images demonstrated the ability to clean chicken feathers of soapnuts extracts (Fig. 3).

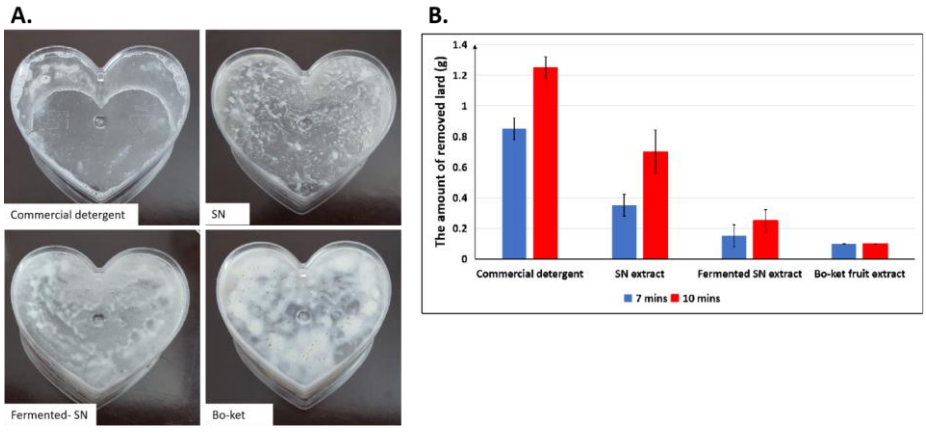

Figure 2. The cleaning activity of natural detergents. A. The grease remains in plastic dishes after they have been soaked and washed 3 times for 10 mins with various detergents. B. The graph shows the amount of lard removed by different detergents over the different time periods. SN: soapnuts.

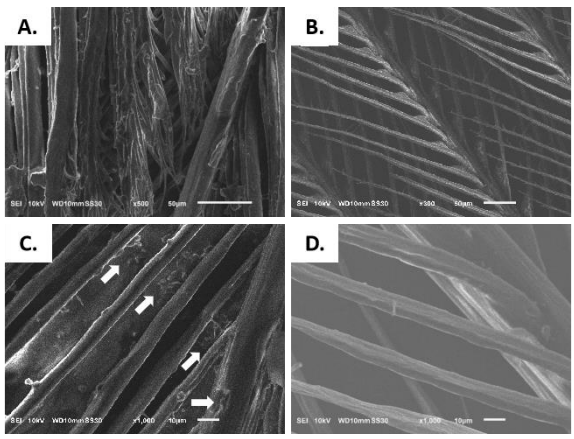

Figure 3. SEM Images of un-washed (A, C) and the soapnut extract-washed feathers (B, D) with different magnifications. Arrows indicate the grease on the chicken feather.

3.2. Chicken Feathers-oil Absorbers

3.2.1 Oil Absorbent Pillow from Poultry Feathers

The thin and long feathers of poultry are quite difficult to use in the real world as well as to evaluate their oil absorption efficiency in the laboratory, therefore we have created a pillow-type oil absorber. In which, poultry feathers washed by different solutions are put into sealed non-woven bags (Fig. 4).

3.2.2 Effect of cleaning solutions on the oil-absorbent ability of chicken feathers.

The ability of unwashed chicken feathers to absorb oil is slow and ineffective in relation to grease and dirt adhering to them. However, the use of commercial and toxic cleaners in large quantities to clean chicken feathers can lead to adverse environmental impacts. Here, we have evaluated the possibility of using natural detergents derived from plant extracts which are popular in Vietnam to treat chicken feathers for making green oil absorber. However, cleaning by commercial detergents appeared to be cleaner than the one using the natural solution and therefore significantly increased the oil absorption capacity of chicken feathers ($p < 0.01$). However, cleaning with unfermented soapnut extract shows great potential as an alternative to commercial and toxic cleaners. Optimizing extraction and treatment conditions of soapnuts may increase their cleaning efficiency (Fig. 5).

There is no significant difference between chicken feathers treated with commercial dish washing liquid and soapnut extract in absorbing lubricant oil ($p>0.5$). And the amount of lubricant oil absorbed by chicken feathers treated with soapnut extract (14.7 g/g) is a little less than that by chicken feathers treated with SDS (16.21 g/g) [3], and much higher (11.33 g/g) than that of chicken feathers treated with sodium bicarbonate (6.1 g/g) in absorbing vegetable oil [2]. This result once again confirms the potential of using natural cleaning solutions as an alternative to commercial chemical products.

3.2.3 Chicken feathers' ability to absorb different oils

We also evaluated the capacity of chicken feathers in absorbing the different kind of oils. Interestingly, the ability to absorb different oils of chicken feathers washed with commercial dish washing liquid remained virtually unchanged (Fig. 5). Meanwhile, the higher the oil viscosity, the higher the oil absorption capacity of chicken feathers treated with natural detergents ($p<0.01$) (Fig. 5B). However, in the cases of used lubricants (data not shown), the excessive viscosity and contaminants [14] prevented the penetration of oil into pores, so the oil absorption efficiency is clearly reduced, markedly in most cases.

The ability to re-absorb oil from used pillows has been evaluated, however, the

efficiency is quite low. This may involve incomplete oil removal, here we used the conventional pressing method. However, the development direction of these studies is to use chicken feathers to absorb oil that is difficult to recover in wastewater of seafood processing plants, then recycle chicken feathers with absorbed oil to make feed. Therefore, the reuse of oil-absorbing materials is not our research goal.

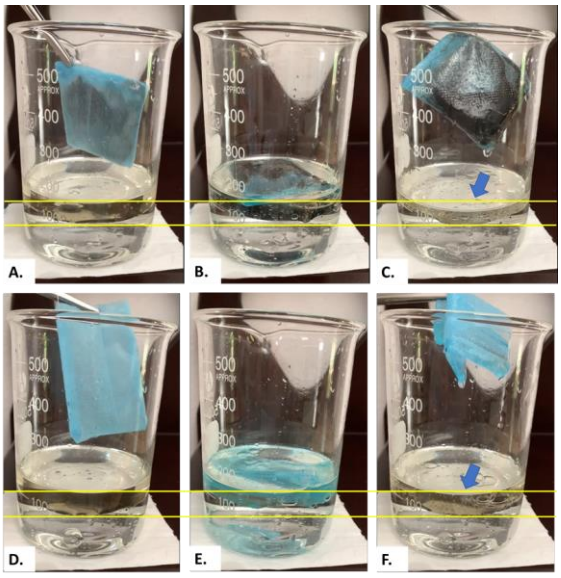

Figure 4. Oil absorbent pillow from poultry feathers. (A-C), Oil-absorbing pillows containing washed chicken feathers dipped in an oil-water mixture. (D-F), The outer cover of the oil absorbent pillow was also tested for oil absorption, with the amount of oil absorbed being negligible. The thick arrows indicate the amount of oil that has been sucked away by the absorbent pillow (C) or by the cover bag of the pillow only (F).

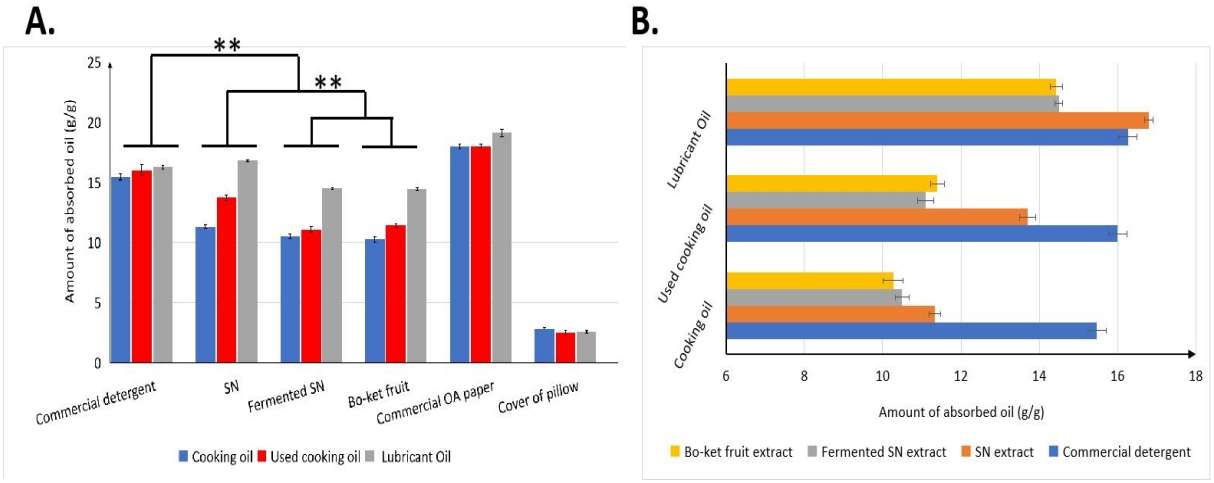

Figure 5. Effect of cleaning solutions and the kind of oil on the oil-absorbent ability of chicken feathers. A. Column graph shows the amount of oil absorbed by the pillows containing chicken feathers treated with different detergents, compared with commercial absorbent paper. B. The interaction plot indicates the interaction between treated conditions and the kind of oil to the absorbent ability of chicken feathers. SN: soapnut extract. Bo-ket fruit: Bo-ket fruit extract. OA: oil-absorbent. **, $p<0.01$.

4. Conclusion

The cleaning activity of natural detergents including soapnut extract, fermented soapnut extract, and bo-ket fruit extract has been investigated and evaluated in our studies. In particular, the soapnut extract shows potential as an alternative to industrial cleaners and toxic chemicals in cleaning chicken feathers on large scale. Our research also once again confirms the use of chicken feathers as a green oil absorber. We have also created an oil-absorbing pillow containing washed chicken feathers with a maximum oil absorption efficiency of 16.8 g/g of material. However, further studies to improve the oil absorption efficiency of chicken feathers need to be conducted to achieve the same efficiency as the commercial plastic product of 19.1 g/g.

Acknowlegement

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