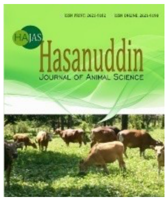

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Physicochemical Properties of Chicken Nuggets with Various Types of Flour Substitutes and Carrot Addition

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ABSTRACT

This study aimed to analyze the effect of using wheat flour, breadfruit flour, and a combination of both, as well as the addition of carrots, on the quality of chicken nuggets. This study was conducted in two experimental stages using a Completely Randomized Design (CRD). Stage I used a 3x4 factorial RAL pattern with 3 repetitions. Factor A (Type of flour) consisted of wheat flour (X), a mixture of wheat flour and breadfruit flour (Y), and breadfruit flour (Z). Factor B (flour level) included 7.5%; 15%; 22.5%; and 30%. Stage II used a single-factor RAL with four treatments of carrot addition levels (P): 7.5%; 15%; 22.5%; and 30% each repeated three times. The research parameters included cooking loss, meat shear force, and water holding capacity (stage I) as well as cooking loss, meat shear force, water holding capacity, dietary fiber, and β-carotene (stage II). Phase I research showed that the type and level of flour had a very significant effect (P<0.05) on water holding capacity and meat shear force. The use of 15% breadfruit flour and 30% carrot gave the best resulted in cooking loss (5.00%), β-carotene (245.13 μg/100g) and dietary fiber (5.82%).

Keywords: Nuggets, breadfruit flour, carrots, physicochemical properties

INTRODUCTION

As food technology and innovation advance, there is a notable shift in consumption behaviors across the population. Urban residents, especially children, increasingly favor ready-to-eat foods, which offer the advantage of rapid preparation and service. Nuggets and sausages exemplify this trend, highlighting the demand for convenience in modern diets.

The susceptibility of chicken meat to damage is largely attributed to its ease of microbial contamination. As a preventive measure, transforming chicken into nugget products can serve as an effective solution to reduce this risk. Broiler chicken meat has a chemical composition of 75.24% water, 22.92% protein, and 1.15% ash [1]. The broiler chicken is categorized as a source of animal protein with essential amino acids contained, and plays an important role in the growth and health of all individuals [2] [3]. Broiler meat has many advantages; it is high in nutrients and tender, compared to other types of meat [4] [5]. The chicken meat is easily damaged if the process is defective. Therefore, it needs more treatment to prevent damage and also maintain the quality of chicken meat. One of the procedures is processing the chicken meat into a processed product, as evidenced by the chicken nugget [6].

Nuggets are currently the most popular processed meat product among the public. Nugget is a processed product of finely ground meat, seasoned and mixed with other binders, then moulded into a certain shape, steamed and dipped in eggs and breadcrumbs, then fried and stored in a freezer [7].

Chicken nuggets are an example of a restructured meat processed product that consists of beneficial nutrition and is also affordable for everyone. Furthermore, the nutritional composition of chicken nuggets includes protein, fat, carbohydrates, and minerals. Nevertheless, the fiber content in chicken nuggets is deficient [8]. The consumer demand for chicken meat products enriched with fiber has increased since dietary fiber has a positive effect on human health [9].

The formulation of nuggets involves the use of fillers that effectively bind water while having a limited effect on the emulsification process [10]. Among these fillers, flour is a key ingredient. It functions as both a filler and a binder, which contributes to enhanced stability, mitigates emulsion shrinkage during cooking, offers a light color, increases elasticity, and results in a dense and attractive texture. The filler material commonly used in the manufacture of nuggets is wheat flour because there is a protein content that can form the texture and give elasticity to the product, namely gluten, but wheat fiber content is relatively low at 1.89% [11]. To increase the levels of fiber, protein, β-carotene, and vitamins in nuggets, diversification of nugget products can be done by utilizing local ingredients that have high fiber, vitamin, and protein content. One of the local food ingredients that can be utilized is breadfruit flour and carrots.

Breadfruit can be converted into flour, which is notable for its starch content of around 75%, a protein concentration of 5%, and a fat content of approximately 2%. In addition to its rich carbohydrate and protein composition, which is low in fat, breadfruit flour also includes 5.4 grams of fibre and 15.1 micrograms of β-carotene. This nutritional profile positions breadfruit flour as an effective alternative filling material. The function of starch is to increase water-holding capacity [11]. Breadfruit flour does not contain gluten like wheat and can substitute wheat flour up to 75% in the manufacture of processed foods [12].

Breadfruit flour is obtained from old breadfruit, which is processed through a flouring process. Breadfruit flour is used as an intermediate product because it has a high nutritional content, so it can be used by the community. Breadfruit flour is used to support breadfruit nutrition as a suitable additional ingredient in the manufacture of food products such as noodles, bread, cakes, and other processed food products [13].

Chicken nuggets, as one of the fast-food items, are popular for their taste and affordability, but unfortunately, they do not contain enough dietary fiber. A lack of dietary fiber can generally lead to digestive problems such as constipation, and prolonged dietary fiber deficiency is even worse, as it can lead to bowel cancer, obesity, and cardiovascular disease [14].

Dietary fiber can generally be fulfilled by consuming vegetables. Vegetables that are easily available at affordable prices are carrots. Carrots are very suitable if added to processed chicken nuggets and can fulfill and increase nutritional needs in the body. Carrots are rich in fiber, such as pectin, cellulose, hemicellulose, and lignin, which can help good bacteria in the intestines so that intestinal function and health can be maintained, and also prevent constipation. Carrots also contain several compounds such as carotenoids, lutein, lycopene, anthocyanins as antioxidants, and β and α carotene, which process vitamin A, as well as several other vitamins such as K, B1, B2, B3, B5, B6, B9, B12, and the mineral Potassium, which is useful for various bodily functions [15].

MATERIALS AND METHODS

The materials used in this study were broiler chicken breast obtained from RPA "Mitra Usaha", organic breadfruit flour 270 g, tapioca flour 165 g, wheat flour 150 g, carrot vegetables 150 g, salt 80 g, garlic 160 g, pepper powder 32 g, chicken eggs 640 g, flavoring 80 g, ice cubes 480 g, panir flour 800 g, labels, clear plaster and tissue obtained from Sungguminasa People's Market, Somba Opu kecematan, Gowa district.

The tools used in this research are *spectrophotometer,* (UV-VIS Shimadzuuv-1800), *food processor* (Cosmos Blenz CB-802), blender, vacuum pump, food dehydrator (Getra ST-02 capacity 100 L), applicator, digital scale (SF 400) capacity 1000 g, basin, stove, pot, spoon, plate, bowl, label, clear plaster, tissue, knife, cutting board, frying pan, spatula, fork, test tube, tube rack and refrigerator.

This research was conducted in two stages experimentally using a completely randomized design (CRD) 3x4 factorial pattern in stage I, and each treatment was repeated three times. Factor A is A_1 wheat flour, A_2 breadfruit flour, and A_3 breadfruit flour mixture. Factor B is B_1 7.5%, B_2 15%, B_3 22%, B_4 30%. Stage II used a completely randomized design (CRD) with five treatments, and each treatment was repeated three times. The treatments consisted of P1 7.5% (15% breadfruit flour, 7.5% carrot), P2 15% (15% breadfruit flour, 15% carrot), P3 22.5% (15% breadfruit flour, 15% carrot), P4 30% (15% breadfruit flour, 30% carrot).

Nugget Making

The process of preparing chicken nuggets began with the cleaning of chicken breast meat, which was subsequently chopped into smaller pieces to facilitate grinding. After the meat was ground to a smooth consistency, it was combined with the necessary ingredients specific to the recipe and ground once more until a uniform mixture was achieved. The resulting nugget mixture was then placed into the designated molds or onto a cutting board for shaping. After the dough had been shaped, it underwent steaming for a duration of 30 minutes. Once fully cooked, the nuggets were allowed to cool. Upon reaching a suitable temperature, they were cut into pieces according to the desired shape. Before frying, the nugget pieces were coated with wet flour, which acted as an adhesive to prevent the dough from disintegrating during the frying process. Subsequently, the nuggets were coated with panir flour. Once the panir flour had been applied, the nuggets were placed in a container and stored in the freezer for 30 minutes. This step was intended to enhance the adherence of the panir flour to the nuggets.

Measured Variable

The measured variables are the physicochemical properties of chicken nuggets, which include:

Cooking Loss

The nugget cooking loss test was conducted following the methodology standard [16]. A 10 g sample was placed in a plastic container and subjected to cooking in a pan at a temperature of 80° C for a duration of 15 minutes. Subsequently, the sample was drained and gently blotted with a tissue to remove excess surface moisture, after which it was reweighed. *Cooking loss* (CL) value was calculated using the following formula:

$$Cooking\ Loss\ \% = \frac{Weight\ before\ cooking - Weight\ after\ cooking}{Weight\ after\ cooking} x\ 100\%$$

Shear Force

The assessment of meat shear force is conducted utilizing the CD-Shear Force instrument, which quantifies the Shear Force (SF) in kilograms per square centimeter.

$$Shear\ Force = \frac{a}{L}$$

Description:
a = Power used (kg),
L = Cross-sectional area of the sample (πr 2 =13.14x (0.635cm)2= 1.27

Water Holding Capacity

Water Holding Capacity (WHC) analysis was conducted employing the Hamm method [17], utilizing a sample weight of 0.3 grams. The sample was wrapped in filter paper and subsequently subjected to a pressure of 35 kg for a duration of 5 minutes between two plates, utilizing a modified Filter Paper Press. Following this, the filter paper was positioned beneath tracing paper, and the resulting area was sketched. The WHC value for the meat samples was determined using the formula D/T x 100%, where D represents the area of the meat and tracing paper combined, and T denotes the total area. The calculations for both the total area (T) and the area of the meat samples (D) were performed using specialized software.

$$Water\ Holding\ Capacity\ (\%) = \frac{D}{T} x\ 100\%$$

Description:
D = Area of meat sample
T = Total area

Dietary Fiber

Dietary Fiber (DF) analysis was performed in accordance with the methodologies [18]. Initially, 2 g samples were placed into sealed test tubes, followed by the addition of 30 ml of 0.3 N H2SO4. The samples were then subjected to extraction in boiling water for a duration of 30 minutes. Subsequently, 15 ml of 1.5 N NaOH was introduced, and extraction continued for an additional 30 minutes. The resulting mixture was filtered through sintered glass No. 1 under a vacuum pump, followed by successive washing with 50 cc of hot water, 50 cc of 0.3 N H2SO4, and 50 cc of alcohol. The filtered residue was then dried in an oven for 8 hours or left overnight, after which it was cooled in an applicator for 30 minutes and weighed (a grams). The sample was then subjected to freezing in an electric furnace for 3 hours at 500 °C, allowed to cool slightly, and placed in an applicator for another 30 minutes before being weighed again (b grams). The DF was subsequently determined through calculation.

$$\%DF = \frac{A - B}{W} x\ 100\%$$

Description:
A = Constant sample weight
B = Area of total ash weight
W = initial weight of sample

B-Carotene

A qualitative analysis was conducted utilizing a 25% solution of antimony trichloride dissolved in chloroform. The outcomes of the extraction were presented as a solution. An aliquot of 2 mL was measured, to which 1 mL of the antimony trichloride solution was subsequently added [19].

RESULTS AND DISCUSSIONS

Stage I

Cooking loss

The research results obtained for the cooking loss test of chicken nuggets with the substitution of various types of flour at different levels are presented in Table 1. The analysis of variance indicates that substituting different types of flour at different levels has a significant effect (P<0.01). The treatment involving 30% wheat flour + breadfruit flour exhibited the highest average CL at 8.84%, while the treatment with 15% breadfruit flour recorded the lowest at 3.69%. Notably, the addition of 15% breadfruit flour yielded the most favorable average CL [20]. Meat exhibiting lower CL is generally of superior quality compared to that with higher shrinkage, as it results in reduced nutrient loss during cooking. Furthermore, the results from Duncan's post hoc test, as presented in Table 1, indicate that the various substitution treatments and flour addition levels significantly differed (P<0.01) in terms of cooking loss in the nuggets. Specifically, the 7.5% and 15% treatments were found to be significantly different from the 22.5% and 30% treatments.

The analysis of variance conducted on the two factors revealed that the interaction resulting from the substitution of different types of flour at varying levels had a highly significant impact (P>0.05) on the CL of nuggets. This interaction suggests that the incorporation of various flour types plays a crucial role in influencing the cooking characteristics of the nuggets.

Table 1. Average of Cooking Loss Value (%) of Nuggets with the Substitution of Different Types of Flour at Different Levels

Flour Level (%)	Flour Type			Average
	Wheat flour	Wheat flour + Breadfruit flour	Breadfruit flour	
7.5	4.06±0.38	6.80±0.55	3.90±0.51	**4.92±1.47[a]**
15.0	4.13±0.32	6.65±0.59	3.69±0.41	**4.82±1.43[a]**
22.5	4.75±0.35	8.28±0.85	4.74±0.25	**5.92±1.83[b]**
30.0	4.53±0.38	8.84±0.44	4.11±0.28	**5.83±2.28[b]**
Average	**4.37±0.42[a]**	**7.64±1.11[b]**	**4.11±0.52[a]**	**5.37±1.78**

Notes: Different superscripts in the same row/column indicate highly significant differences (P<0.01)

Shear Force

The research results obtained for the shear force test of chicken nuggets with the substitution of various types of flour at different levels are presented in Table 2. The analysis of variance regarding the substitution of various flour types at different levels revealed a highly significant impact (P<0.01) on the SF of nuggets. The highest average SF value was observed in the treatments incorporating 7.5% and 15% wheat flour (0.21%), while the lowest was noted with the addition of 7.5% and 15% breadfruit flour (0.13%). Measurements of cooking loss indicated that the inclusion of 30% breadfruit flour yielded the most favorable average nugget shear force [21]. A lower SF value correlates with increased tenderness in nuggets, whereas a higher value indicates greater toughness. The results from Duncan's post hoc test (as presented in Table 2) demonstrate that the various flour substitution treatments at different levels resulted in significantly different outcomes (P<0.01) concerning nugget shear force. Notably, the 30% treatment exhibited significant differences when compared to the 7.5%, 15%, and 22% treatments.

Table 2. Average of Shear Force (kg/cm^2) Value with the Substitution of Different Types of Flour with Different Levels

Flour Level (%)	Flour Type			Average
	Wheat flour	Wheat flour + Breadfruit flour	Breadfruit flour	
7.5	0.21±0.01	0.15±0.02	0.13±0.01	0.16±0.03[b]
15.0	0.21±0.00	0.15±0.01	0.13±0.01	0.16±0.03[b]
22.5	0.20±0.00	0.15±0.01	0.15±0.01	0.17±0.03[b]
30.0	0.14±0.01	0.14±0.01	0.14±0.01	0.14±0.00[a]
Average	0.19±0.03[c]	0.15±0.01[a]	0.14±0.01[a]	0.16±0.03

Notes: Different superscripts in the same row/column indicate highly significant differences (P<0.01)

The variance analysis conducted on the two factors revealed that the interaction between the substitution treatments of various flour types at differing levels had a highly significant effect

(P>0.05) on the SF of the nuggets. This interaction suggests a relationship between the incorporation of different flour types and their effects on the overall properties of the product.

Water Holding Capacity

The research results obtained for the water-holding capacity test on chicken nuggets with the substitution of various types of flour at different levels are presented in Table 3. The analysis of variance regarding the substitution of various flour types at different levels revealed a highly significant impact (P<0.01) on the WHC of the nuggets. The highest average water holding capacity was observed in the treatment with 15% breadfruit flour, measuring 69.66%, while the lowest was recorded in the treatment with 7.5% wheat flour, at 49.64%. Lapase et al. [22], meat with a low water-holding capacity tends to lose a substantial amount of liquid, leading to weight reduction. A lower WHC correlates with increased CL, which adversely affects meat quality due to the degradation of various components. Therefore, it can be concluded that the optimal treatment involves the addition of 15% breadfruit flour. Furthermore, the results of Duncan's multiple range test presented in Table 3 indicate that the different flour substitution treatments yield significantly distinct effects (P<0.01) on the WHC of the nuggets. Notably, the 7.5% treatment exhibited significant differences from all other treatments, whereas the 15% and 22.5% treatments did not show significant differences between them.

Table 3. Average of WHC (%) of Nuggets Substituted with Different Types of Flour at Different Levels

Flour Level (%)	Flour Type			Average
	Wheat flour	**Wheat flour + Breadfruit flour**	**Breadfruit flour**	
7.5	49.64±3.21	51.66±3.62	57.34±0.73	52.66±4.02^{a}
15.0	51.68±0.58	51.00±1.81	69.66±0.56	57.67±9.18^{b}
22.5	52.68±0.52	50.28±0.32	68.10±0.07	57.02±8.38^{b}
30.0	64.52±3.99	65.95±0.15	61.86±4.68	64.11±3.56^{c}
Average	54.63±6.46^{a}	54.72±7.00^{a}	64.24±5.54^{b}	57.86±7.68

Notes: Different superscripts in the same row/column indicate highly significant differences (P<0.01)

The analysis of variance conducted on the two factors revealed that the interaction resulting from the substitution of various types of flour at different levels had a highly significant impact (P>0.05) on the WHC of the nuggets. This interaction suggests a relationship between the treatment of flour substitution and the varying levels employed.

Stage II

Physicochemical Properties

The research results obtained for the substitution of 15% breadfruit flour with the addition of carrots on its physicochemical properties are presented in Table 4.

Table 4. Average of Physicochemical Values of 15% Breadfruit Flour Substitution Nuggets with Carrot Addition

Variable	Treatment (%)				Average
	7.5	15	22.5	30	
Cooking loss (%)	16.66±2.88[b]	10.00±8.66[ab]	5.00±0.00[a]	5.00±0.00[a]	9.16±6.33
Shear Force (kg/cm^2)	0.17±0.01	0.14±0.02	0.13±0.03	0.12±0.02	0.14±0.02
WHC (%)	55.15±803	59.36±6.36	61.33±8.69	61.80±1.71	59.41±6.45
Betacarotene (%)	61.44±0.52[a]	171.15±0.39[b]	214.84±0.65[c]	245.13±0.27[d]	173.14±72.74
Dietary Fiber (%)	1.28±0.03[a]	1.70±0.04[b]	4.21±0.05[c]	5.82±0.15[d]	3.25±1.94

Notes: Different superscripts in the same row/column indicate highly significant differences (P<0.01).

Cooking Loss

The analysis of variance regarding the substitution of 15% breadfruit flour combined with carrots yielded statistically significant results (P<0.05), indicating that the incorporation of these ingredients influences the average CL of the nuggets. Specifically, the highest CL was observed in the treatment involving 7.5% breadfruit flour and carrots, which recorded a value of 16.66%. Conversely, the lowest average CL was noted in the treatments with 22.5% and 30% breadfruit flour and carrots, both showing a value of 5.00%. It was found that CL increased proportionally with the concentration of carrots. Verma and Banerjee [23] suggested that the fibre content in carrots can effectively bind water in sausage products. Highlighted that fibre is capable of retaining water, thereby minimizing cooking loss [23].

The findings presented in Table 4 from Duncan's test indicate that a 15% substitution of breadfruit flour, combined with the inclusion of carrots, results in a significant difference (P<0.01) in the CL of the nuggets. Specifically, the addition of carrots at a level of 7.5% differs from the levels of 22.5% and 30%, whereas the 15% carrot addition does not show a significant difference when compared to the 7.5%, 22,5%, and 30% levels.

Shear Force

The analysis of variance regarding the substitution of 15% breadfruit flour combined with carrots revealed no statistically significant effect (P>0.05) on the average SF values. This indicates that the incorporation of breadfruit flour and carrots did not influence the SF measurements. The treatment with 7.5% breadfruit flour and carrots yielded the highest average SF value at 0.17%, while the treatment with 30% breadfruit flour and carrots resulted in the lowest average value of 0.12%. It was observed that as the concentration of breadfruit and carrot flour increased, the SF values decreased, suggesting that the nuggets became more tender. Wibowo [24], that substituting tapioca flour with breadfruit flour can preserve the elasticity of meatballs. When breadfruit flour is used in its entirety, the role of pectin becomes significant. This observation aligns with Wibowo's [24] assertion that variations in the elasticity of meatballs can stem from factors such as protein, moisture, and fat content in the constituent ingredients.

Water Holding Capacity

The analysis of variance regarding the substitution of 15% breadfruit flour with the inclusion of carrots indicated that there was no statistically significant effect (P>0.05). This suggests that the incorporation of breadfruit flour and carrots did not influence the WHC of the nuggets. Anneke et al. [25], who attributed breadfruit flour's water-binding capability to that of tapioca flour, attributed it to its high carbohydrate content.

The findings indicate that the average water-holding capacity of nuggets is influenced by the substitution of 15% breadfruit flour combined with carrots. The highest WHC was recorded at 30% breadfruit flour and carrot treatment, achieving a value of 61.80%. Conversely, the lowest average water holding capacity was observed with a 7.5% addition of breadfruit flour and carrots, resulting in a value of 55.15%. An increase in the proportion of breadfruit and carrot flour correlates with an enhancement in the WHC of the nuggets. Agustin [26] that the carbohydrates present in breadfruit contribute to increased water retention. Furthermore, Suryaningsih [27] highlights that the elevated amylopectin content in breadfruit flour leads to a greater spacing between myofibril proteins, thereby preventing water from escaping the formed cavities and resulting in a higher WHC in meatballs.

B-Carotene

The analysis of variance regarding the substitution of 15% breadfruit flour combined with the addition of carrots revealed a highly significant effect (P>0.01) on the β-carotene content in the nuggets. The average values indicated that the highest β-carotene concentration was achieved with a treatment involving 30% breadfruit flour and carrots, yielding a value of 245.13%. Conversely, the lowest average β-carotene content was recorded in the treatment with a 7.5% addition of breadfruit flour and carrots, which resulted in a value of 61.44%. This increase in β-carotene levels in the nuggets correlates positively with the rising concentration of carrots used in the formulation. Bungan [28] states that β-carotene is present in various fruits and vegetables, including apricots, tomatoes, mangoes, carrots, pumpkin, and papaya.

The findings presented in Duncan's test (as illustrated in Table 4) indicate that a 15% substitution of breadfruit flour, when combined with carrots, results in a statistically significant difference (P<0.01) in the β-carotene content of the nuggets. The addition of carrots at a level of 7.5% was found to differ from the levels of 15%, 22.5%, and 30%, and the reverse was also true. Yulianawati and Isworo [29] Note that β-carotene is a type of carotenoid that serves as a provitamin A and functions as an effective antioxidant, particularly at low oxygen concentrations.

Dietary Fiber

The analysis of variance regarding the substitution of 15% breadfruit flour with the incorporation of carrots revealed a highly significant effect (P<0.01) on the DF of the nugget product. The average values indicated that the highest DF was achieved with a 30% carrot addition, yielding a value of 5.82%, while the lowest average DF was recorded with a 7.5% carrot addition, at 1.28%. This indicates a positive correlation between the levels of breadfruit and carrot incorporation and the resultant DF. It is noted that the inclusion of various vegetables, such as carrots, in processed nugget products is intended to enhance dietary fibre levels [30].

The findings presented in Table 4 from Duncan's test indicate that the substitution of 15% breadfruit flour, combined with the inclusion of 30% carrots, resulted in a significantly higher DF

(P<0.01) when compared to the treatments with 7.5%, 15%, and 22.5%. This suggests a positive correlation between the level of vegetable incorporation and the enhancement of DF in the nuggets. These findings confirm that increasing the level of carrot addition results in a higher dietary fiber content in chicken nuggets. The incorporation of carrots as an additional ingredient in processed products such as nuggets contributes to improved nutritional quality, particularly by enhancing the dietary fiber content. The fiber content of chicken nuggets is influenced by the additional ingredients used; the greater the proportion of high-fiber raw materials, the higher the fiber content of the nuggets [31].

CONCLUSIONS

The substitution of different types of flour at varying levels in Stage I showed that the addition of 15% breadfruit flour produced the best results in terms of cooking loss (3.69%), nugget breaking force (0.13%), and water-holding capacity (69.66%). In Stage II, the use of 15% breadfruit flour combined with 30% carrot in the nugget formulation yielded the best results, with cooking loss of 5.00%, β-carotene content of 245.13 μg/100 g, and dietary fiber content of 5.82%.

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AUTHORS' CONTRIBUTIONS

Conceptualized the study and drafted and revised the manuscript. All Author: Conducted experiments and analyzed data. All authors have read and approved the final manuscript.

COMPETING INTERESTS

The authors declare that there is no conflict of interest in this research and publication.

ETHICAL CLEARANCE

The authors have ethical clearance for the use of animal products in research.

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