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Formulation of High Protein and Fiber Soy-Based Chicken Nugget

Carollynna Baba[1], Hatijah Basri[1*]

[1] *UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 84600 Pagoh, Muar, Johor.*

*Corresponding Author: hatijah@uthm.edu.my
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Abstract

Chicken nuggets are a popular processed meat product composed of chicken, flour, and preservatives usually made from processed chicken meat, often containing a combination of chicken breast, skin, breadcrumbs, egg, herbs and spices. Due to health concerns, chicken nugget was decreased in popularity because of the less healthy ingredients, additives and processing method during the production. To address this, four soy-based chicken nugget formulations were developed, by focusing on protein enhancement and dietary fibre while reducing fat content at the same time. These formulations varied in the percentage of Okara used: 30 %, 50 %, 60 %, and 80 %. The comparison between four formulations of soy-based chicken nuggets and two commercial nuggets were conducted during this study. The comparison includes characterization of chicken nuggets such as pH, moisture content, texture, and colour (L* a* b* values). Results showed that all the values significantly ($p<0.05$) differ for each sample. The sensory evaluations are conducted by considering attributes like appearance, aroma, taste, aftertaste and overall acceptance. Except for appearance and colour, there was a significant difference between the samples in terms of aroma, texture, taste, aftertaste and overall acceptance. From the sensory evaluation, formulation 1 and 3 are more preferred in term of all sensory attributes compared to other formulations based on overall acceptance. These formulations underwent proximal analysis and compared with commercial nuggets for protein, dietary fibre, and fat content. Results showed that formulations 1 and 3 are higher in protein, dietary fibre, and fat per 100 g which are 15.4 g, 0.2 g and 9.1 g for formulation 1 and 12.4 g, 0.7 g, and 9.0 g respectively for formulation 3 compared with commercial nuggets, making them promise healthier alternatives for consumers.

1. Introduction

Chicken nuggets have become a staple food item, particularly in the fast-food industry. People of various ages, including children, teenagers, and adults, enjoy them. Chicken nuggets are popular choices for quick snacks or on-the-go meals due to their convenience [1]. The growth of fast-food restaurants like McDonald's, Burger King, and KFC was a major factor in the rising popularity of chicken nuggets. These chains heavily promote chicken nuggets as part of their menus, leading to increased consumer exposure and demand.

Nowadays, the consumers are becoming more health-conscious and are looking for more wholesome protein options, rich in dietary fibre and low in fat at the same time the product are rich in flavour, good taste and mouthfeels. The addition of artificial additives, flavour enhancers, and preservatives in chicken nuggets may contribute to gastrointestinal issues, allergic reactions, and adverse metabolic effects over prolonged periods [2]. Processing of foods has gained more attention from the general public and researchers based on a international organisations (such as the Food and Agriculture Organisation and the World Health Organisation) about chronic diseases brought on by improper diets and lifestyle habits [3]. Therefore, it is essential to limit the consumption of processed chicken nuggets and option for healthier alternatives that are prepared using lean meats, whole grains, and natural ingredients to mitigate potential health risks and promote overall well-being.

The demand for plant-based protein alternatives has steadily increased in recent years. Many consumers are looking for healthier foods that contain less saturated fat and cholesterol [4]. Plant-based protein sources such as legumes, soy, nuts, and seeds generally contain less saturated fat and can provide important nutrients such as fibre, vitamins and minerals. Okara is a one of good source of plant-based protein. The protein content of nuggets made from okara may vary depending on the recipe and processing method. On average, okara contains about 20-25% protein. However, the protein content in the final product may be higher due to the addition of other plant-based protein sources or enrichment [5].

In this study, 4 formulations of soy-based chicken were developed by using Okara as main ingredient for each formulation. These formulations are to reduce the amount of chicken breast and skin in the nugget. Okara is rich in fibre, protein and other nutrients, making it a valuable ingredient for various applications [6]. Okara are usually contains about 20-25% protein by weight. The protein in okara is easily digestible and can be a valuable source of protein for vegans, vegetarians or people who want to reduce their consumption of animal protein. Okara is a good source of dietary fibre and provides several health benefits. However, the exact fibre content may vary depending on factors such as soybean variety and production process [7].

By using Okara as a main ingredient in nugget formulation, it will reduce the usage of chicken breast and skin in nugget. The Okara are expected to enhance the protein and dietary fibre in the formulation of chicken nugget. Hence, the formulation of nugget should higher protein and dietary fibre compared to commercial nugget. In addition, the amount reduction of chicken breast and skin in each formulation may affect the total fat of the chicken nugget. The nugget flavour and texture may also be affected using Okara that has strong flavour and mushy texture as a main ingredient instead of chicken will be affecting the consumer acceptance of food. This research is to produce 10 to 20 grams of protein and 0.1 to 1.0 gram of fibre in formulations of soy-based chicken nuggets compared to commercial nugget.

2. Materials And Methods

2.1 Materials

The soy pulp (Okara) was purchased from soymilk producer at Kangkar, Tebrau, Johor. chicken breast, chicken skin, soy sauce, salt, black pepper, white pepper, eggs, powdered onion, powdered paprika, powdered garlic, chicken seasoning, breadcrumbs, soybean oil, palm oil were purchased at local market in Bukit Gambir and Pagoh Jaya, Johor. Sodium Tripolyphosphate (STPP) was purchased from Dchemie Malaysia, Skudai, Johor.

2.2 Methods

2.2.1 Preparation Of Soy-Based Chicken Nugget

The byproducts Okara were purchased from Soymilk production factory. Four nugget formulations were prepared by increasing the amount of Okara and reducing the amount of chicken breast and chicken skin for each formulation. The ingredients used were weighed separately by referring to the formulation from (Echeverria et al., 2022). The formulation was shown in Table 2.1. A bowl chopper is used to grind chicken meat and skin, respectively. The other ingredients are added and homogenized for 5 minutes. The paste was moulded into nuggets of around 36 grams. Then, chicken nuggets were pre-fried in soybean oil at 180-200 ˚C for 30 seconds and oven-fried at 170 ˚C for 15 minutes. The products were stored in polyethylene bags (one per formulation and batch) and frozen at -18 ˚C [8].

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Table 2.1 *The formulations of ingredients used in the preparation of soy-based chicken nugget (Echeverria et al., 2022).*

Ingredients (g 100g^{-1})	**Formulations**			
	1	2	3	4
Chicken Breast	50.0	30.0	20.0	10.0
Chicken Skin	15.5	7.75	na	na
Breadcrumbs	10.0	15.0	20.0	25.0
Okara	30.0	50.0	60.0	80.0
Eggs	10.0	10.0	10.0	10.0
Soy Sauce	0.12	0.12	0.12	0.12
Refine Salt	0.10	0.10	0.10	0.10
Black pepper	0.15	0.15	0.15	0.15
White pepper	0.15	0.15	0.15	0.25
Powdered Onion	0.20	0.20	0.20	0.20
Powdered Garlic	0.14	0.14	0.14	0.15
Powdered Paprika	0.10	0.10	0.10	0.10
Chicken Seasoning	0.10	0.10	0.10	0.10
Sodium Tripolyphosphate	0.03	0.03	0.03	0.03

na = not added.

2.2.2 Cooking Of Soy-Based Chicken Nugget

Frozen nugget pieces were removed from the freezer and fried directly using a frying pan. The frying temperature need ranged from 184 ˚C to 188 ˚C for 3-4 minutes. After that, nuggets pieces were strained to remove oil, cooled and packed in polyethylene bags for further evaluation.

2.2.3 Colour Evaluation

The colour of all six samples of soy-based chicken nugget was evaluated by using a colorimeter to obtain colour values. The L*, a*, b* indicate the lightness coefficient, red colour coefficient, yellow colour coefficient [9].

2.2.4 Texture profile analysis (TPA)

TPA was performed using a texture analyzer (TVT 6700, Perten, Sweden), previously calibrated with a standard weight of 2 kg and using a load cell of 5 kg and a 40 mm diameter cylinder probe. All cooked chicken nugget pieces from each formulation and two commercial nuggets are undergo this analysis. Circular samples (2 x 1 cm) was cutting from nugget pieces and tested using the following profile: Test mode with Compression Pre-Test Speed: 1.50 mm/sec, Test speed: 1.50 mm/sec Post-Test Speed: 10.00 mm/sec. The T.A. variable are No: 5: 0.0 g with target Mode: Distance: 30.000 mm. The Strain: 10.0 % Trigger with probe hdp/bsw; blade set with warner

bratzler. Each sample was analysed as firmness (N) and work of shear (N.sec). The result of firmness and work of shear giving us the indicator of textural properties parameter including springiness, cohesiveness, and gumminess of soy-based chicken nugget [10].

2.2.5 pH Value

A five grams sample of chicken nuggets of each formulation and 2 commercial nuggets are taken and homogenized with 45 mL distilled water using a blender. Then, the sample were measured using digital pH meter [11].

2.2.6 Moisture Content

The appropriate amount of soy-based chicken nugget is weighed for each sample. Around 5-10 grams of sample were used for this analysis. After finishing the sample preparation, it was placed inside the moisture analyzer [12] until the final reading of percentage moisture is shown.

2.2.7 Sensory Evaluation

The sensory analysis of chicken nuggets was performed using the Hedonic Test, with 60 panellists participating. Each panellist was presented with 6 samples including 2 commercial nuggets to determine their preferred sensory attributes such as appearance, colour, texture, aroma, taste, and aftertaste and overall acceptance of the product. In this hedonic test, a 9-point scale was used to score the attributes according to the sensory characterization. The best two formulation of soy-based chicken nugget from this analysis are chosen for the proximal composition analysis of protein, dietary fibre and fat to compare with 2 commercial nuggets.

2.2.8 Proximal Composition

The methodologies of the Association of Official Agricultural Chemists – AOAC were used to determine the contents proteins (method 920.87), lipids (method 920.85) and dietary fibres (method 985.29) [13].

2.2.9 Statistical Analysis

The analysis for all six samples were carried out triplicates. The data from the analyses were expressed as mean and standard deviation. One-way analysis of variance (ANOVA) is performed using Minitab Software and Microsoft Excel to determine statistically significant differences between the 6 samples of soy-based chicken nuggets. The level of statistical were defined at $p \leq 0.05$ where the p value below or equal to 0.05 are regarded as significant.

3. Results and Discussion

3.1 Colour Evaluation

Table 3.1 listed the values of different amounts of Okara, chicken, herbs, spices, additives and other ingredients that caused colour changes to soy-based chicken nugget. The colour of Okara is generally white or yellowish in colour, with a creamy beige [14]. The result shows that the highest value of Lightness (*L) is formulation 1 and the lowest value is commercial B. The values are $30.313^{ab} \pm 0.015$ and $29.187^{c} \pm 0.015$ respectively. This indicates that formulation 1 is more towards lightness while commercial B more towards black. Hence, the appearance of formulation 1 is paler than commercial B.

The positive value indicates that all the sample are more toward redness than the green colour. The highest a* among the sample is formulation 3 and the lowest value is commercial A. The value of the sample is $2.283^{a} \pm 0.015$ and $1.033^{d} \pm 0.015$ respectively. So, the colour of formulation 3 are redder compared to commercial A. This is due to the breadcrumbs added to the formulation 3 that cause the colour of the formulation 3 became red. Apart from that, the positive value of b* indicates that all the sample more towards yellow than the blue.

The highest value is formulation 4 and the lowest is commercial B. The b* are $5.590^{a} \pm 0.017$ and $1.110^{f} \pm 0.010$ respectively. The yellowish colour of formulation 4 is higher than other sample is due to the highest amount of okara added to the formulation compared to other which is 80 of okara per 100 grams. In addition, the breadcrumbs added to the formulation 4 also give the yellowish colour of the soy-based chicken nugget of formulation 4. All the colour values significantly ($p<0.05$) differ for each sample.

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Table 3.1 *Colour value of soy-based chicken nuggets*

Colour	**L***	**a***	**b***
Value			
Sample			
Formulation 1	$30.313^{ab} \pm 0.015$	$2.247^{a} \pm 0.015$	$2.980^{d} \pm 0.000$
Formulation 2	$30.737^{a} \pm 0.592$	$1.970^{b} \pm 0.010$	$3.737^{c} \pm 0.012$
Formulation 3	$30.430^{ab} \pm 0.036$	$2.283^{a} \pm 0.015$	$3.933^{b} \pm 0.015$
Formulation 4	$30.060^{b} \pm 0.010$	$1.770^{c} \pm 0.020$	$5.590^{a} \pm 0.017$
Commercial A	$29.390^{c} \pm 0.010$	$1.033^{d} \pm 0.015$	$2.047^{e} \pm 0.021$
Commercial B	$29.187^{c} \pm 0.015$	$1.063^{d} \pm 0.015$	$1.110^{f} \pm 0.010$

*The data is presented from mean of triplicate determinations ± SD

3.2 Texture Profile Analysis (TPA)

From Table 3.2, **c**ommercial A exhibited the highest firmness value, indicating a denser or more compact structure, requiring greater force for compression compared to the softer formulation A, which contained 80% Okara per 100 grams, known for its soft texture. Formulation 4 has a lower firmness than commercial A, aligning with its softer consistency. Regarding shear resistance, commercial A had the highest work of shear, reflecting greater internal cohesion or resistance to mastication forces, resulting in a chewier texture. In contrast, formulation 4 registered the lowest work of shear, indicating less internal resistance, leading to a more tender and less chewy texture. ANOVA analysis confirmed significant differences ($p<0.05$) in both firmness and work of shear across all samples, highlighting distinct textural attributes between commercial and formulated soy-based chicken nuggets.

Table 3.2 *Firmness and work of shear of soy-based chicken nuggets*

Sample	Firmness (N)	Work of Shear (N.sec)
	Force	Force-Time
Formulation 1	$7.7553^{e} \pm 0.0003$	$88.2778^{c} \pm 0.0016$
Formulation 2	$7.8582^{d} \pm 0.0114$	60.0084 ± 0.0007
Formulation 3	$12.3914^{c} \pm 0.0001$	$65.1538^{cd} \pm 0.0013$
Formulation 4	$5.9211^{f} \pm 0.0002$	$36.0141^{e} \pm 0.0008$
Commercial A	$62.3227^{a} \pm 0.0002$	$386.7030^{a} \pm 0.0020$
Commercial B	$34.2543^{b} \pm 0.0001$	$272.000^{b} \pm 20.800$

*The data is presented from mean of triplicate determinations ± SD

3.3 pH value

The pH variations observed in the chicken nugget formulations are attributed to differences in composition, particularly the varying amounts of Okara, along with the influence of added ingredients such as salt, spices, herbs, and fat [15]. The inclusion of sodium tripolyphosphate in all formulations (1 to 4) and the processing method, involving pre-cooking with soybean oil before freezing and analysis, also contributed to the observed pH differences [16]. Analysed results revealed pH values ranging between 6.00 and 6.30 across all samples, with formulation 1 exhibiting the highest pH at $6.230^{b} \pm 0.010$ and formulation 4 registering the lowest. An ideal pH range of 5.8 to 6.3 for soy-based chicken nuggets, promoting microbial safety and product quality [17]. Gratifyingly, all formulations, including commercial samples, fell within this recommended pH range, ensuring

safety and quality attributes. ANOVA analysis confirmed significant differences ($p<0.05$) among the samples in terms of pH values, affirming the impact of formulation and processing on the acidity of the nugget.

Table 3.3 *pH values of soy-based chicken nuggets*

Sample	pH Value
Formulation 1	$6.230^{b} \pm 0.010$
Formulation 2	$6.170^{c} \pm 0.010$
Formulation 3	$6.107^{d} \pm 0.015$
Formulation 4	$6.050^{e} \pm 0.010$
Commercial A	$6.347^{a} \pm 0.011$
Commercial B	$6.153^{c} \pm 0.006$

*The data is presented from mean of triplicate determinations ± SD

3.4 Moisture Content

Moisture content is an important parameter influencing the texture, consumer acceptability, and overall quality of soy-based chicken nuggets, typically ranging between 50% to 65% [17][18]. Analysed samples in Table 3.4 revealed moisture content spanning from 44% to 60%. Commercial B exhibited the lowest moisture at $44.533^{f} \pm 0.015\%$, potentially leading to dryness and less palatability [19]. Conversely, Formulation 3 recorded the highest moisture content at $59.457^{a} \pm 0.012\%$, aligning with ideal parameters for enhanced texture, flavour, and juiciness without compromising quality [18]. Significantly, all samples demonstrated a p-value less than 0.05, confirming distinct moisture variations rooted in diverse ingredients and processing factors, rather than random variability, underscoring their unique impacts on product quality and sensory attributes.

Table 4.4 *Moisture content (%) of soy-based chicken nuggets*

Sample Soy-Based Chicken Nugget	Moisture Content (%)
Formulation 1	$59.030^{b} \pm 0.010$
Formulation 2	$58.487^{c} \pm 0.006$
Formulation 3	$59.457^{a} \pm 0.012$
Formulation 4	$57.287^{d} \pm 0.015$
Commercial A	$52.267^{e} \pm 0.015$
Commercial B	$44.533^{f} \pm 0.015$

*The data is presented from mean of triplicate determinations ± SD

3.5 Sensory Evaluation

The results of sensory evaluation of soy-based chicken nugget were evaluated as seen in Fig. 4.1 and Table 4.5 below. The sensory evaluation of soy-based chicken nuggets involved 60 panellists assessing six samples from four distinct formulations and two commercial variants, using attributes such as appearance, aroma, colour, texture, taste, aftertaste, and overall acceptance. Notably, no significant difference in appearance was observed among samples ($p>0.05$), yet sample 603 was preferred with a score of $7.557^{a} \pm 1.756$, while 718 scored the lowest at $6.852^{a} \pm 1.806$. Significant aroma differences were noted ($p<0.05$), with sample 603 favoured ($7.803^{a} \pm 1.759$) and 259 least preferred ($6.246^{c} \pm 1.578$), likely due to varying Okara content influencing soy aroma intensity. Colour did not differ significantly ($p>0.05$), yet 603 and 718 led in preference scores ($7.443^{a} \pm 1.784$ and 6.787a ± 1.743, respectively). Texture variance was significant ($p<0.05$), with 603 perceived as chewier ($7.705^{a} \pm 1.874$) and 924 softer ($5.213^{c} \pm 1.781$), attributed to the 80% Okara content in 924. Taste and aftertaste also varied significantly ($p<0.05$), with 603 favoured and 924 less so due to soybean aftertaste. Overall, commercial samples 603 and 841 dominated, while formulations 379 and 259 stood out, as confirmed by ANOVA indicating significant differences ($p<0.05$) in overall acceptability across samples.

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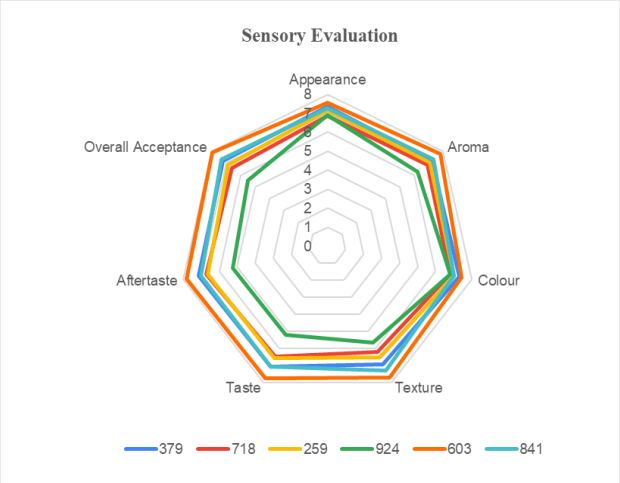

Fig. 4.1 *Spider web for 9-points hedonic scale test*

Table 4.5 *Sensory results for each attribute of each sample*

CODE	Appearance	Aroma	Colour	Texture	Taste	Aftertaste	Overall Acceptance
379	7.344^{a} ± 1.611	7.197^{ab} ± 1.590	7.312^{a} ± 1.566	6.918^{ab} ± 1.563	7.066^{ab} ± 1.401	7.131^{ab} ± 1.544	7.213^{ab} ± 1.416
718	6.852^{a} ± 1.806	6.885^{bc} ± 1.624	6.787^{a} ± 1.743	6.213^{b} ± 1.664	6.475^{b} ± 1.719	6.721^{b} ± 1.752	6.623^{b} ± 1.485
259	7.131^{a} ± 1.668	7.066^{ab} ± 1.632	7.016^{a} ± 1.618	6.541^{b} ± 1.649	6.574^{b} ± 1.893	6.623^{b} ± 1.916	6.853^{b} ± 1.631
924	6.885^{a} ± 1.529	6.246^{c} ± 1.578	6.803^{a} ± 1.492	5.639^{c} ± 1.693	5.213^{c} ± 1.781	5.230^{c} ± 1.970	5.525^{c} ± 1.659
603	7.557^{a} ± 1.756	7.803^{a} ± 1.759	7.443^{a} ± 1.784	7.705^{a} ± 1.874	7.754^{a} ± 1.823	7.803^{a} ± 1.768	7.934^{a} ± 1.682
841	7.262^{a} ± 1.741	7.344^{ab} ± 1.702	7.000^{a} ± 1.932	7.295^{ab} ± 1.706	7.049^{ab} ± 1.919	7.033^{ab} ± 1.966	7.344^{ab} ± 1.816

*The values are presented as mean ± SD

3.6 Proximal Composition

The proximal composition analysis played a crucial role in determining the nutritional and sensory attributes of soy-based chicken nuggets, focusing on protein, dietary fibre, and total fat content per 100g unit. Selected formulations from sensory evaluation, namely formulation 1 and formulation 3, were analysed alongside two commercial counterparts, commercial A and commercial B. Based on Table 4.6, formulation 1 has the highest protein content, attributed to the inclusion of Okara and chicken breast, leading to a rich protein composition [20][21]. In contrast, commercial B recorded the lowest protein content, possibly due to minimal incorporation of these protein sources. Dietary fibre analysis revealed formulation 3 as the frontrunner, incorporating 60% Okara, a recognized source of dietary fibre [22]. Conversely, formulation 1 contained 30% Okara, resulting in a lower fibre content. Regarding total fat, commercial B exhibited the highest value at 13.6g, while commercial A recorded the lowest at 7.8g, aligning with typical fat content ranges observed in soy-based chicken nuggets [23]. Despite variations, all analysed samples adhered to established nutritional parameters, emphasizing the intricate balance of ingredients in influencing proximal composition and product quality.

Table 4.6 *Proximal composition of soy-based chicken nuggets per 100 grams*

Parameter	Unit	Protein	Dietary Fiber	Total Fat
Sample	g/100 g			
Formulation 1	g/100 g	15.4	0.2	9.1
Formulation 3	g/100 g	12.4	0.7	9.0
Commercial A	g/100 g	12.8	0.5	7.8
Commercial B	g/100 g	10.2	0.1	13.6

4. Conclusion

The four formulations of soy-based chicken nuggets were enhanced protein and fibre content, aligning with the rising demand for sustainable protein sources like soy. Through formulation adjustments, especially in increasing Okara content, both protein and dietary fibre levels were notably increased, surpassing those of two commercial nuggets. Characterization of nugget confirmed satisfactory results in pH, moisture, colour, and texture parameters where the *p* values from the analysis were less than 0.05. This value indicated the significant different between the samples. Furthermore, sensory evaluations affirmed that these formulations achieved favourable scores across attributes such as texture, appearance, aroma, taste, and aftertaste. Ultimately, the developed soy-based chicken nugget formulations effectively matched commercial counterparts in overall acceptability based on sensory panel feedback.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Carollynna Baba, Hatijah Basri;* ***data collection:*** *Carollynna Baba;* ***analysis and interpretation of results:*** *Carollynna Baba, Hatijah Basri;* ***draft manuscript preparation:*** *Carollynna Baba, Hatijah Basri. All authors reviewed the results and approved the final version of the manuscript.*

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