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Nutritional Value of Bitterballen Substituted with Pumpkin and Snakehead Fish as Alternative Protein-Source Snack for School-Age Children

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Abstract: Protein-energy deficiency in school-age children is one of the problems caused by malnutrition in Indonesia. The potential local food ingredients can be used to prevent protein-energy deficiency. This research was conducted to determine the effect of substituting snakehead fish and pumpkin on the nutritional value of bitterballen. This research is an experimental study. The substitution of pumpkin and snakehead fish was made using four formulas, namely control F0 with no substitution (0:0); F1 with 1:4 subtitution; F2 with 1:3 subtitution; F3 with 1:2 subtitution. The nutritional value of energy, protein, fat, and total carbohydrate was assessed to analyze the portion recommendation. The data was analyzed using SPSS with the One-way ANOVA (Post-Hoc Tukey) test to determine differences in nutritional content in each formulation. The energy content of raw bitterballen was increased from 217.76 to 239.63 kcal (F1-F3) but decreased sequentially after cooking (238.8-208.5 kcal). The protein content of raw bitterballen was increased by 10.21%-12.37% (F1-F3), and it was decreased sequentially (9.87%-9.65%) after frying. The fat content was increased drastically in all formulations after cooking, from around 1.82%-2.6% in raw bitterballen (F1-F3) to 7.88%-8.25% in fried one. Total carbohydrate content was decreased both in the raw (25.53%-20.20%) and fried bitterballen (23.29%-19.19%). In raw bitterballen, the energy content was higher, mainly due to the increase in protein and fat from the addition of snakehead. The carbohydrate content decreased with adding pumpkin since it contains relatively low carbohydrates. We conclude that F1 has the most optimal amount of protein and energy compared to other formulas after frying. The recommended portion for a snack is two pieces of fried bitterballen (50 g) per serving to meet the energy-protein needs of school-age children.

Keywords: bitterballen; local food substitution; protein-energy malnutrition; school-age snacks

1. INTRODUCTION

Growth and development are important stages of a child's life. The balance between a child's nutritional needs and intake needs to be met for the growth and development process because nutritional status at primary school affects nutritional and health status in adulthood [1]. Malnutrition can occur if the intake of nutrients in energy and protein is low for a long period. One of the factors of PEM in school-age children is influenced by the consumption of snacks and drinks at school, especially the quantity and quality [2]. School-age children tend to consume foods that look good but are not necessarily good for their health [3]. Based on basic health reseach [4] data in Indonesia, as many as 44.4% and 30.6% of children in Indonesia consume energy and protein below the nutritional adequacy rate (RDA). Thus, it is necessary to develop protein-source snack products to meet the daily needs of energy-protein in children.

A product that can be developed as a protein energy source to prevent nutritional problems in school-age children is bitterballen. Bitterballen has a savory taste, and the shape of the balls [5], resembles school snacks on the market that making it attractive and suitable for school-age children's snacks. This can be an opportunity to make bitterballen innovations by utilizing local food ingredients to maintain the original Indonesian taste and culinary identity. Bitterballen can be modified with various food ingredients to support food security [6] and create a formulations as protein-source snacks.

Local food ingredients that have the potential to be utilized in products with high nutritional value include pumpkin and snakehead fish. Pumpkin can be used to substitute wheat flour in the manufacture of various food products [7]. The availability of pumpkin is easy to reach, and its production is more than sufficient. However, pumpkin has a low protein content, so it needs to be combined with protein source ingredients. Snakehead fish has various benefits such as the source of protein, antioxidants, and anti-inflammatory with different nutritional content such as amino acids, fatty acids, minerals, and vitamins [8]. Snakehead fish has a superior content of protein and albumin, which is higher than several other types of fish [9] explained by 16,2 grams of protein found in every 100 gram of snakehead fish [10]. The use of meat in original recipe of biterballen may substituted with snakehead fish since it has relatively similar high content of protein with lower economic value. The combination of the two ingredients is expected to be a protein energy source snack, which hopefully able to reach broader need of protein to prevent PEM.

2. MATERIALS AND METHODS

The samples used in this study were bitterballen substituted with snakehead fish and pumpkin, consisting of four formulations that refer to the research on the development of tilapia and red bean bitterballen products by Wijaya [11] and modified pumpkin substitution of catfish nuggets by Permadi et al. [12]. Control F0 without the addition of pumpkin and snakehead fish (0:0); F1 with 12.5% pumpkin substitution and 50% snakehead fish (1:4); F2 with 25% pumpkin substitution and 75% snakehead fish (1:3); F3 with 50% pumpkin substitution and 100% snakehead fish (1:2).

The bitterballen consists of minced beef and snakehead fish, combined with steamed pumpkin following the formulation. Additional components like carrots, milk, flour, cheese, garlic, onions, and salt are incorporated. The combination is cooked until it reaches uniform consistency and then left to cool at room temperature. Subsequently, the dough is shaped into 25 grams each and coated with breadcrumbs using egg as an adhesive agent. The bitterballen are then deep-fried for serving. It was produced at the Laboratory for Product Development located in the Faculty of Medicine, Public Health, and Nursing at Universitas Gadjah Mada.

The evaluation of macronutrient levels was conducted at the Chem-mix Laboratory, Yogyakarta, Indonesia. Tests of energy, protein, fat, and carbohydrate content used three measurements from each formulation (triplo). Energy measurements were carried out using the bomb calorimetry method, protein using the Kjeldhl method, fat using the Soxhlet method, and total carbohydrates by difference. Tests were conducted on raw and cooked samples that had been deep-fried.

Data analysis was carried out using SPSS with the multivariate ANOVA (MANOVA) test to determine the difference in nutritional value among various formulations, comparing raw and fried bitterballen. The variables that showed significant differences were further analyzed using the One-way ANOVA (Post-Hoc Tukey) test to determine differences of nutritional content in each formulation and paired t-test to evaluate the cooking process. This research has received approval from the Health Medicine Research Ethics Commission, Faculty of Medicine, Public Health, and Nursing, Gadjah Mada University, with letter number KE-FK-0580-EC-2024.

3. RESULTS AND DISCUSSION

The results of energy, protein, fat, and total carbohydrate content of the bitterballen formula were tested for normality using Shapiro-Wilk, and it was found that all data were normally distributed ($p>0.05$) (Table 1). The multivariate ANOVA (MANOVA) was showed that nutritional content among formulations and cooking process significantly different ($p<0.05$), therefore we need analyzed further for the mean difference in formulation and cooking process.

Table 1. The Nutritional Content of Bitterballen Substituted with Pumpkin and Snakehead Fish

Formulation		Energy (kcal)	*p*-value	Protein (%)	*p*-value	Fat (%)	*p*-value	Total Carbohydrate (%)	*p*-value
F0	Raw	203.75±201	0.510	9.23±0.08	0.816	1.68±0.14	0.289	25.95±0.05	0.999
	Fried	251.47±0.68	0.597	10.53±0.13	0.382	7.45±0.07	0.095	24.88±0.06	0.637
F1	Raw	217.76±0.76	0.994	10.21±0.05	0.613	1.82±0.12	0.257	25.53±0.04	0.999
	Fried	238.80±1.28	0.945	9.87±0.09	0.100	7.88±0.04	0.977	23.29±0.10	1.000
F2	Raw	235.38±0.34	0.266	11.60±0.08	0.850	2.29±0.16	0.732	22.24±0.08	1.000
	Fried	229.88±2.37	0.164	9.77±0.02	0.251	8.13±0.07	0.380	21.80±0.05	0.999
F3	Raw	239.63±1.11	0.494	12.37±0.10	0.720	2.63±0.18	0.144	20.20±0.06	0.636
	Fried	208.50±6.85	0.925	9.65±0.07	0.605	8.25±0.04	0.648	19.19±0..05	1.000

The results of the Tukey-type Post Hoc test were mostly showed significant differences in the amount of energy, protein, and carbohydrates between each formulation. But for fat content in raw bitterballen, the difference between F0-F1, F1-F0, F1-F2, F2-F3, F3-F1 and F3-F2 were not significant. In fried bitterballen some formulation did not showed significant difference, the energy and protein content in F1-F2 and F2-F1; also the fat content in F2-F3 and F3-F2. The difference of energy, protein, fat and carbohydrate in cooking process was shown in Table 3. The difference of protein content in F1 and total carbohydrate in F2 were not significant in raw and fried bitterballen.

Table 2. The Difference of Nutritional Value on Biterballen Formulation

	Formulation x Formulation		Raw		Fried	
			Mean Difference	*p*-value	Mean Difference	*p*-value
Energy	F0	F1	14.01	0.000	12.67	0.013
		F2	31.63	0.000	21.60	0.000
		F3	35.88	0.000	42.97	0.000
	F1	F0	14.01	0.000	12.67	0.013
		F2	17.62	0.000	8.92	0.071*
		F3	21.87	0.000	30.30	0.000

Continued Table 2..

	F2	F0	31.63	0.000	21.60	0.000
		F1	17.62	0.000	8.92	0.071*
		F3	4.24	0.012	21.37	0.000
	F3	F0	35.88	0.000	42.97	0.000
		F1	21.87	0.000	30.29	0.000
		F2	4.25	0.012	21.37	0.000
Protein	F0	F1	0.98	0.000	0.67	0.000
		F2	2.36	0.000	0.76	0.000
		F3	3.13	0.000	088	0.000
	F1	F0	0.98	0.000	0.66	0.000
		F2	1.38	0.000	0.10	0.053*
		F3	2.15	0.000	0.21	0.066
	F2	F0	2.36	0.000	0.76	0.000
		F1	1.38	0.000	0.10	0.053*
		F3	0.77	0.000	0.11	0.043
	F3	F0	3.13	0.000	0.88	0.000
		F1	2.15	0.000	0.21	0.066
		F2	077	0.000	0.11	0.043
Fat	F0	F1	0.33	0.266*	0.43	0.000
		F2	1.14	0.001	0.68	0.000
		F3	0.80	0.005	0.80	0.000
	F1	F0	0.33	0.266*	0.43	0.000
		F2	0.81	0.005	0.25	0.003
		F3	0.47	0.079*	0.37	0.000
	F2	F0	1.14	0.001	068	0.000
		F1	0.81	0.005	0.25	0.003
		F3	033	0.252*	0.11	0.144*
	F3	F0	0.80	0.005	0.79	0.000
		F1	0.47	0.079*	0.37	0.000
		F2	0.33	0.252*	0.11	0.144*
Total Carbohydrate	F0	F1	0.42	0.000	1.60	0.000
		F2	3.69	0.000	3.08	0.000
		F3	5.74	0.000	5.69	0.000
	F1	F0	0.42	0.000	1.60	0.000
		F2	3.29	0.000	1.49	0.000
		F3	5.33	0.000	4.10	0.000
	F2	F0	3.69	0.000	3.08	0.000
		F1	3.29	0.000	1.49	0.000
		F3	2.04	0.000	2.61	0.000
	F3	F0	5.74	0.000	5.69	0.000
		F1	5.33	0.000	4.09	0.000
		F2	2.04	0.000	2.61	0.000

F3 gave significant differences in energy, protein, and total carbohydrate content. F1 was only significant in fat and total carboydrate content, while F2 was only in carbohydrate content. Meanwhile, deep frying gave significant energy and fat content differences in all formulations. The difference in protein content after deep frying was significant in F2 and F3, and carbohydrate in F1 and F3.

Table 3. The Difference of Nutritional Value on Cooking Process

	Raw x Fried	Mean Difference	*p*-value
Energy	F0	47.54	0.010
	F1	21.31	0.003
	F2	6.74	0.003
	F3	35.08	0.003
Protein	F0	1.29	0.004
	F1	0.35	0.081*
	F2	1.88	0.003
	F3	2.63	0.009
Fat	F0	5.76	0.007
	F1	6.15	0.004
	F2	5.38	0.002
	F3	6.06	0.002
Total Carbohydrate	F0	1.07	0.005
	F1	2.17	0.010
	F2	0.42	0.080*
	F3	107	0.013

The average energy content of bitterballen substituted with different amounts of pumpkin and snakehead fish is displayed in Table 1. The average energy content increased significantly from F0 to F3 in raw bitterballen. The average test values of energy content in raw bitterballen F0, F1, F2, and F3 were 203.75 kcal/g, 217.76 kcal/g, 235.38 kcal/g, and 239.63 kcal/g, respectively. The increase in energy content from F0 to F3 can be attributed to the additional nutrients from pumpkin and snakehead fish. Snakehead fish, being a high-protein food, contributed to the overall increase in calories content.

The average test values of energy content in cooked bitterballen F0, F1, F2, and F3 were 251.47 kcal/g, 238.80 kcal/g, 229.88 kcal/g, and 208.50 kcal/g, respectively. The increase in energy content in F0 after frying is expected, as frying adds fat, which increases the caloric density [13]. However, the decrease in energy content bitterballen substitued with pumpkin and snakehead fish may be due to the complex interaction between the ingredients during the frying process. High heat could cause moisture loss or degradation of specific nutrients in these formulations, resulting in lower energy content [14]. Additionally, the substitution with pumpkin and snakehead fish, which contain water and protein, could lead to the release of water during frying, subsequently lowering the energy content.

The decrease in energy content in F1, F2, and F3 can also be partly explained by protein damage caused by high temperatures during the frying process. Proteins are sensitive to heat, and excessive cooking can lead to denaturation or the formation of non-nutritive compounds, which may lower their contribution to the total energy content [15].

The protein content increased significantly from formula F0 to F3 in raw bitterballen. The average test results of protein content in raw bitterballen F0, F1, F2, and F3 are 9.23%, 10.21%, 11.6%, and 12.37%, respectively. This trend indicates that the incorporation of snakehead fish, contributed to the increase in the overall protein percentage. Snakehead fish is a rich source of high-quality protein, which enhances the protein profile of the bitterballen as more of it is substituted into the formulation.

At the same time, in fried products, there was a decrease in protein content along with the addition of snakehead fish to bitterballen; F0, F1, F2, and F3 respectively were 10.53%, 9.87%, 9.77%, and 9.65% respectively. During frying, the high temperatures can cause the delicate fish proteins to degrade or form insoluble aggregates (excessive denaturation or hydrolysis), reducing their availability and measurable content [16]. This could account for the progressive decrease in protein content from F1 to F3, despite the increase in raw protein content.

Meat-based products (such as F0) tend to retain more of their protein content during frying due to the greater heat stability of meat proteins. According to research by [16], fish proteins degrade more readily at high temperatures due to their less stable structure compared to meat proteins, leading to a reduction in available protein after cooking. Product moisture is lost during frying, which can lead to an increase in the relative concentration of some nutrients, including protein [17]. This likely explains the slight increase in protein content observed in F0 (from 9.23% in raw to 10.53% in fried). The higher moisture content in snakehead fish and pumpkin, combined with the release of water during frying, may prevent a significant concentration of protein in the fried products.

The average fat content increased from F0 to F3 in raw and cooked bitterballen. The average test values of fat content in raw bitterballen F0, F1, F2, and F3 were 1.68%, 1.82%, 2.29%, and 2.63%, respectively. After frying, the fat content increased significantly in all formulations, from F0 to F3 respctively were 7.45%, 7.88%, 8.13%, and 8.25%, respectively.

This substantial increase in fat content after frying can be explained by the absorption of frying oil during the cooking process. The oil absorption during frying increases the fat content, thereby reducing the concentration of proteins and other macronutrients [18].

Formulations containing pumpkin and fish (F1 to F3) likely have higher moisture content, which evaporates during frying, allowing more oil to be absorbed into the food matrix [19]. Thus, the increase in fat content from F0 to F3 could be due to the addition of more snakehead fish and pumpkin. Additionally, the protein content from the snakehead fish could influence the product's oil-holding capacity, further increasing fat absorption during frying. The increase in fat content after frying is typical in foods that undergo deep-fat frying, where both nutrient interactions and the physical properties of ingredients affect the final composition [20].

The average total carbohydrate content decreased from F0 to F3 in raw and cooked bitterballen. The average test values of the total carbohydrate content in raw bitterballen F0, F1, F2, and F3 are 25.95%, 25.53%, 22.24%, and 20.20%, respectively. Pumpkin, while containing some carbohydrates, is also a source of fiber and water, which could dilute the overall carbohydrate percentage when added in larger amounts [21].

The total carbohydrates content in cooked bitterballen F0, F1, F2, and F3 were 24.88%, 23.29%, 21.80%, and 19.19%, respectively. The reduction in carbohydrate content post-frying can be linked to several factors, notably the Maillard reaction, which occurs when reducing sugars react with amino acids during cooking. The Maillard reaction is a key factor in the cooking of protein-rich foods, particularly those containing sugars [22]. This complex reaction not only contributes to the browning and flavor development in cooked foods but also results in the consumption of available carbohydrates, leading to a decrease in their measurable content.

Based on the nutritional content of fried-bitterballen, the portion recommendation was calculated refer to the daily nutritional needs of school-age children. Daily intake of snacks was around 10% of total energy, the protein intake recommendation for ages 7-9 years old was 4 grams, and for ages 10-12 years old was 5 grams per day. Generally, the recommended portion is around two pieces of bitterballen (all formulations) to fulfill daily protein requirements.

Table 4. The calculation of bitterballen portion recommendation based on daily protein needs of school-age children

Formulation	Protein per serving 25 g (g)	Age of 7-9		Age of 10-12	
		Protein needs (g)	Portion (serving)	Protein needs (g)	Portion (serving)
F0	2.6	4	1.5	5	1.9
F1	2.5	4	1.6	5	2
F2	2.4	4	1.7	5	2.1
F3	2.4	4	1.7	5	2.1

4. CONCLUSION

The substitution of bitterballen with pumpkin and snakehead fish 1:2 (F3) showed the most significant difference in nutritional content, especially for energy and protein. Overall, while the substitution of pumpkin and snakehead fish increased the energy content in raw bitterballen, frying caused a decrease. Frying reduces the protein levels, particularly in fish-containing formulations, facilitated by moisture loss. The decrease in protein content post-frying in F1, F2, and F3 is likely due to the denaturation of fish proteins and fat absorption.

This highlights the importance of considering ingredient interactions and cooking methods when developing protein-source food products, as they can significantly impact the final nutritional content. Portion recommendations on bitterballen with or without pumpkin and snakehead fish showed similar results. In conclusion, bitterballen substituted with pumpkin and snakehead fish can be an alternative protein source snack for school-age children.

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