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Nutritional potential of processed sago grub (*Rhynchophorus ferrugineus*) and smoked tilapia (*Oreochromis mossambicus*) products as local protein sources for food diversification in Papua

Rosmin Mariati Tingginehe[1], Yacob Ruru[2]*, Anneke Yacob[3], Wilma Florensia[1]

[1]Department of Nutrition, Faculty of Public Health, Cenderawasih University, Jayapura, Papua, 99351, Indonesia
[2]Department of Statistics, Faculty of Mathematics and Natural Sciences, Cenderawasih University, Jayapura, Papua, 99351, Indonesia
[3]Department of Epidemiology, Faculty of Public Health, Cenderawasih University, Jayapura, Papua, 99351, Indonesia

**Correspondence:* yacobruru62@gmail.com

ABSTRAK

Latar Belakang: *Kekurangan protein masih menjadi tantangan kesehatan masyarakat di beberapa wilayah Papua, terutama pada kelompok rentan gizi. Pangan hewani lokal seperti ulat sagu (Rhynchophorus ferrugineus) dan ikan mujair asap (Oreochromis mossambicus) telah lama dikonsumsi, namun bukti ilmiah mengenai potensi gizi produk olahannya masih terbatas.*
Tujuan: *Menganalisis komposisi gizi produk olahan berbasis ulat sagu dan mujair asap yang dikembangkan oleh Usaha Mikro, Kecil, dan Menengah (UMKM) di Kampung Yoboi, Kabupaten Jayapura.*
Metode: *Penelitian deskriptif berbasis laboratorium dilakukan pada empat produk olahan, yaitu nugget dan bakso ulat sagu serta nugget dan bakso mujair asap. Analisis meliputi komposisi proksimat, energi total, profil asam lemak (omega-3, omega-6, dan omega-9), serta asam amino esensial. Analisis proksimat dan asam lemak dilakukan tiga kali ulangan menggunakan metode AOAC, sedangkan analisis asam amino dilakukan satu kali. Hasil dinyatakan per 100 g basis basah dan dianalisis secara deskriptif.*
Hasil: *Produk berbasis mujair asap mengandung protein tertinggi, sedangkan produk berbahan ulat sagu memiliki kandungan energi dan lemak yang lebih tinggi. Semua produk mengandung omega-3, omega-6, dan omega-9 dengan rasio omega-6:omega-3 sebesar 1,37–1,85. Profil asam amino esensial memenuhi atau melampaui standar updated FAO/IAEA, dengan kandungan leusin dan lisin yang relatif tinggi.*
Kesimpulan: *Produk olahan berbasis ulat sagu dan mujair asap memiliki kualitas gizi yang baik dan berpotensi sebagai sumber protein lokal. Pengembangannya melalui UMKM dapat mendukung diversifikasi pangan, perbaikan gizi masyarakat, dan ketahanan pangan di Papua.*

KATA KUNCI*:* *ketahanan pangan; komposisi gizi; mujair asap; sumber protein lokal; ulat sagu*

ABSTRACT

Background: *Protein deficiency remains a public health challenge in several regions of Papua, particularly among nutritionally vulnerable populations. Local animal-source foods such as sago grub (Rhynchophorus ferrugineus) and smoked tilapia (Oreochromis mossambicus) have long been consumed; however, scientific evidence regarding the nutritional potential of their processed products remains limited.*

Objectives*: To analyze the nutritional composition of processed products based on sago grub and smoked tilapia developed by micro, small, and medium enterprises (MSMEs) in Yoboi Village, Jayapura Regency.*

Methods: *A laboratory-based descriptive study was conducted on four processed products: sago grub nuggets, sago grub meatballs, smoked tilapia nuggets, and smoked tilapia meatballs. Nutritional analyses included proximate composition, total energy, fatty acid profiles (omega-3, omega-6, and omega-9), and essential amino acids. Proximate and fatty acid analyses were performed in triplicate using AOAC standard methods, while amino acid composition was analyzed once. Results were expressed per 100 g wet basis and analyzed descriptively.*

Results: *Smoked tilapia-based products had the highest protein content, whereas sago grub-based products provided higher energy and fat contents. All products contained omega-3, omega-6, and omega-9 fatty acids, with omega-6 ratios ranging from 1.37 to 1.85. Essential amino acid profiles met or exceeded updated FAO/IAEA standards, with relatively high levels of leucine and lysine observed across all products.*

Conclusions: *Processed products based on sago grub and smoked tilapia demonstrated good nutritional quality and strong potential as local protein sources. Their development through MSMEs may support food diversification, improve community nutrition, and strengthen food security in Papua.*

KEYWORDS*: food security; local protein sources; nutritional composition; sago grub; smoked tilapia*

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INTRODUCTION

Protein inadequacy remains a public health concern in several regions of Papua, particularly among children, pregnant women, and other nutritionally vulnerable groups. Limited access to affordable animal protein sources and reliance on imported foods contribute to poor dietary quality and suboptimal nutritional outcomes. Strengthening the use of locally available food resources is therefore essential to improving nutritional status and supporting regional food security (1). Sago grubs (*Rhynchophorus ferrugineus*) and tilapia (*Oreochromis mossambicus*) are traditional animal-based foods long consumed by Papuan communities. Sago grubs are notable for their high protein and lipid content, particularly their unsaturated fatty acids, which contribute to energy reserves. Tilapia, on the other hand, provides essential amino acids such as leucine and lysine, which are critical for muscle protein synthesis and immune function, as well as micronutrients including calcium, phosphorus, iron, and vitamin B12 that support growth and overall health.

Together, these raw materials offer a complementary nutritional profile that combines high-quality protein, essential amino acids, and key micronutrients needed to address dietary inadequacies in nutritionally vulnerable populations. However, despite their nutritional potential, these foods remain underutilized in contemporary nutrition programs, particularly in processed forms. Globally, edible insects are increasingly recognized as nutrient-dense foods with favorable fatty acid profiles and high-quality protein comparable to conventional livestock and fish (2,3). Similarly, fish and aquatic foods play a critical role in food and nutrition security, especially in resource-limited settings (4). Processing local food resources into value-added products such as nuggets and meatballs can improve consumer acceptance, extend shelf life, and increase economic value while maintaining nutritional quality. Moreover, community-based processing initiatives led by micro, small, and medium enterprises (MSMEs) align with global recommendations for sustainable, environmentally friendly food systems (5). Nevertheless, while the nutritional value of raw sago grubs and tilapia has been well documented, empirical evidence on their processed forms remains limited. Processing into nuggets and meatballs may alter nutrient composition through heating, mixing, and preservation methods, potentially affecting protein quality, fatty acid profiles, and amino acid balance.

Therefore, this study addresses the gap by providing laboratory-based descriptive data on proximate composition, fatty acid profiles, and 55essential amino acid composition of MSME-produced nuggets and meatballs in Yoboi Village, Jayapura Regency. To our knowledge, no published study has comprehensively analyzed these processed products in Papua, making this investigation necessary to evaluate their nutritional integrity and potential role in food diversification and community-based nutrition strategies. To the best of our knowledge, this is the first study in Papua to comprehensively evaluate the proximate composition, fatty acid profile, and essential amino acid content of MSME-produced sago grub and smoked tilapia products intended for food diversification programs.

MATERIALS AND METHODS

This study employed a laboratory-based descriptive design to evaluate the nutritional profile of processed local protein products, chosen to provide a comprehensive overview without comparative hypothesis testing. The research was conducted from January to March 2025 in Yoboi Village, Jayapura Regency, Papua. Four MSMEs-produced products were analyzed: sago grub nuggets, smoked tilapia nuggets, sago grub meatballs, and smoked tilapia meatballs. Raw materials were standardized sago obtained from the same local processing group and smoked tilapia from a single producer to minimize variability and ensure that observed differences reflected processing methods rather than raw material inconsistencies. Nutritional analyses included proximate composition (protein, fat, carbohydrate, moisture, and ash), total energy content, fatty acid profiles (omega-3, omega-6, and omega-9), and essential amino acid composition, evaluated against updated FAO/IAEA reference requirements (22,23,24). Laboratory analyses for proximate composition, energy, and fatty acid profiles were performed in triplicate using standardized methods based on the Association of Official Analytical Chemists (6). Protein was determined by the Kjeldahl method, fat by Soxhlet extraction, moisture by oven drying, ash by furnace incineration, and carbohydrate by difference (6). Fatty acid profiles were analyzed using gas chromatography with flame ionization detection (GC-FID) after conversion to fatty acid methyl esters (FAMEs), following validated procedures for fatty acid determination in food samples (8). Essential amino acids were analyzed once per product batch using High-Performance Liquid Chromatography (HPLC) with standard derivatization procedures (9); therefore, values are reported without standard deviation (SD). All nutrient contents were expressed on a wet basis per 100 to reflect the nutritional value of products in their ready-to-eat form, which is more relevant for dietary assessment and consumer-level interpretation (10). Data obtained from laboratory analyses were analyzed descriptively to illustrate nutritional characteristics and general trends of each processed product. The focus was on documenting nutritional composition under standardized raw material and sampling conditions, with results interpreted as indicative rather than inferential. Data were analyzed descriptively to illustrate nutritional characteristics and general trends. No inferential statistical analysis was performed, as the study design aimed to provide baseline compositional data rather than test hypothesese.

RESULTS AND DISCUSSIONS

The laboratory findings are presented descriptively to highlight the nutritional characteristics and key trends observed in processed sago grub and smoked tilapia products.

Proximate Composition and Energy Content

Table 1 presents the proximate composition and energy content of processed sago grub and smoked tilapia products, expressed on a wet basis per 100 g. Protein content varied considerably across products, with smoked tilapia–based products showing the highest levels (up to 18.05 ± 0.09%). This reflects the intrinsic composition of fish muscle, which is rich in complete proteins and essential amino acids (4,8). In contrast, sago grub–based products exhibited higher fat and energy content due to lipid accumulation in insect larvae, which serves as an energy reserve during development. This characteristic has been consistently reported in edible insect studies, highlighting their high caloric density and lipid contribution (2,3). Carbohydrate content was highest in sago grub meatballs (39.27 ± 0.06%) and lowest in smoked tilapia meatballs (14.14 ± 0.11%).

Energy values reflected these macronutrient differences, with sago grub nuggets providing the highest energy (231.79 ± 0.97 kcal/100 g) and smoked tilapia meatballs the lowest (133.63 ± 0.62 kcal/100 g).From a nutritional perspective, tilapia-based products function primarily as protein sources, while sago grub–based products contribute energy and essential fatty acids. Such complementarity is particularly relevant in addressing protein and energy deficiencies in resource-limited settings, where combining fish and insect-based ingredients can provide balanced dietary contributions to support both energy needs and protein requirements.

Table 1. Proximate composition and energy content of processed sago grub and smoked tilapia products

Product Type	Protein (%)	Fat (%)	Carbohydrate (%)	Energy (kcal)
Sago grub nuggets	7.31 ± 0.08	6.73 ± 0.15	35.51 ± 0.01	231.79 ± 0.97
Smoked tilapia nuggets	18.05 ± 0.09	3.04 ± 0.06	16.73 ± 0.46	166.40 ± 2.04
Sago grub meatballs	3.82 ± 0.08	5.77 ± 0.16	39.27 ± 0.06	224.29 ± 0.83
Smoked tilapia meatballs	12.99 ± 0.08	2.79 ± 0.06	14.14 ± 0.11	133.63 ± 0.62

Note: Values are expressed on a wet weight basis per 100 g. Energy was calculated using the formula: (4 × protein) + (9 × fat) + (4 × carbohydrate).

Fatty Acid Profile

Table 2 presents the fatty acid composition of processed sago grub and smoked tilapia products, expressed as mean ± SD on a wet basis per 100 g. All processed sago grub– and smoked tilapia–based products contained omega-3, omega-6, and omega-9 fatty acids, with omega-9 consistently representing the predominant fraction. The predominance of the measured unsaturated fatty acids (omega-3, omega-6, and omega-9) suggests a potentially beneficial lipid profile in these products. However, since saturated fatty acids were not analyzed, the results should be interpreted cautiously and do not represent a comprehensive assessment of overall lipid quality. Sago grub nuggets exhibited the highest omega-3 content (633.00 ± 0.45 mg/100 g), while sago grub meatballs contained the lowest (66.38 ± 2.20 mg/100 g). Biological, nutritional, and technological factors can explain these differences. Biologically, sago grubs store substantial lipid reserves in their fat body, which are better retained in nugget formulations, whereas meatballs undergo dilution with fillers and binders that reduce omega-3 concentration. Nutritionally, fish muscle tissue contains lower lipid density compared to insect fat bodies, but retains a favorable balance of polyunsaturated fatty acids; this explains why tilapia meatballs showed higher omega-3 levels (305.80 ± 0.42 mg/100 g) than nuggets (205.30 ± 0.14 mg/100 g), as the meatball formulation preserved more of the fish muscle lipids.

Technologically, processing steps such as homogenization, mixing, and heating influence lipid retention: nuggets, which undergo breading and frying, may lose more omega-3 through oxidation and thermal degradation, whereas boiling meatballs better preserves muscle lipids. Comparable findings have been reported in studies on edible insects, where lipid reserves are concentrated in specific tissues (11), and in fish-based products, where cooking methods significantly affect fatty acid stability (12). These results highlight the complementary nutritional roles of insect- and fish-based products, with sago grubs contributing energy-dense lipids and tilapia providing high-quality protein and polyunsaturated fatty acids.

Omega-6 concentrations ranged from 91.17 ± 3.87 mg/100 g in sago grub meatballs to 1,022.30 ± 2.90 mg/100 g in sago grub nuggets, while omega-9 values were highest in sago grub nuggets (2,077.45 ± 6.60 mg/100 g) and lowest in sago grub meatballs (65.81 ± 5.16 mg/100 g). These results highlight the lipid-rich nature of sago grubs, which serve as energy reserves for larvae, compared to tilapia muscle tissue that is relatively lean. The ω6:ω3 ratios of all products ranged from 1.37 to 1.85, well below the updated FAO/IAEA-recommended upper limit of 4:1 (22,23,24). More recent evidence also supports the importance of maintaining low ω6:ω3 ratios, as balanced profiles are associated with reduced inflammation and improved cardiovascular outcomes (14,15). The relatively higher omega-3 content observed in sago grub nuggets may be linked to larval dietary substrates, as sago grubs naturally feed on decaying sago palm tissue rich in starch and lipids, which contributes to their high fat reserves and omega-3 content. In contrast, tilapia products reflect aquatic feed sources, where fish muscle lipids are influenced by plankton and formulated aquaculture diets.

Although detailed feeding conditions of the larvae were not experimentally controlled in this study, previous reports confirm that insect lipid composition is strongly affected by substrate quality (11). At the same time, fish fatty acid profiles are shaped by dietary inputs in aquaculture systems (16). These findings highlight the functional nutritional value of both products, consistent with global evidence that edible insects and fish contribute beneficial polyunsaturated fatty acids essential for cardiovascular health, cognitive development, and inflammatory regulation (1,5).

Table 2. Fatty acid profile of processed sago grub and smoked tilapia products

Product Type	Omega-3 mg/100gr (EPA+DHA+ALA)	Omega-6 mg/100gr (LA+AA)	Omega-9 mg/100gr (Oleate)	ω6:ω3 Ratio
Sago grub nuggets	633.00 ± 0.45	1022.30 ± 2.90	2077.45 ± 6.60	1.61 ± 0.01
Smoked tilapia nuggets	205.30 ± 0.14	340.50 ± 0.85	731.30 ± 1.56	1.66 ± 0.01
Sago grub meatballs	66.38 ± 2.20	91.17 ± 3.87	65.81 ± 5.16	1.37 ± 0.06
Smoked tilapia meatballs	305.80 ± 0.42	567.10 ± 3.11	387.85 ± 2.47	1.85 ± 0.02

Note: Values are expressed as mean ± SD (n = 3), mg/100 g wet basis. GC-FID determined fatty acid composition. The ω6:ω3 ratio is shown as an indicator of fatty acid balance. No inferential statistical analyses were performed.

Essential Amino Acid Composition

Table 3 shows the essential amino acid profiles of processed sago grub and smoked tilapia products, expressed per 100 g protein. Most essential amino acids met or exceeded the updated FAO/IAEA and WHO reference requirements (22,23,24,12), confirming high protein quality.

Leucine and lysine were consistently abundant across all samples, underscoring their importance in muscle protein synthesis, growth, and immune function. Although methionine levels in sago grub meatballs (1.80 mg/100 g protein) were slightly below the FAO/IAEA updated reference value (22,23,24), this limitation was nutritionally compensated by adequate levels of other essential amino acids, ensuring overall protein quality.

These results confirm that both sago grub and tilapia-based products can serve as high-quality protein sources for dietary improvement strategies. The presence of all essential amino acids at or above the updated FAO/IAEA requirements highlights their potential to improve protein intake, particularly in regions where dietary diversity is limited. It should be noted that values are based on a single measurement; therefore, no standard deviation (SD) is reported.

Table 3. Essential amino acid composition of processed sago grub and smoked tilapia products (mg/100 g protein)

Amino Acid	Sago Grub Nuggets (mg/100gr)	Smoked Tilapia Nuggets (mg/100gr)	Sago Grub Meatballs (mg/100gr)	Smoked Tilapia Meatballs (mg/100gr)	FAO/IAEA Requirement
Leucine	7.80	8.00	7.10	7.40	7.00
Isoleucine	3.00	4.10	3.60	3.80	3.00
Valine	4.30	4.40	4.00	4.10	3.50
Lysine	6.80	7.10	6.40	6.70	5.80
Methionine	2.00	2.10	1.80	1.90	2.00
Threonine	3.40	3.50	3.10	3.20	2.50
Phenylalanine	4.40	4.50	4.00	4.10	3.50
Tryptophan	1.20	1.30	1.00	1.10	1.00

Note: Amino acid composition was determined from a single analysis; therefore, variability could not be estimated, and no standard deviation (SD) is reported.

Comparative Nutritional Potential and Implications

The complementary nutritional characteristics of sago grub and smoked tilapia–based products suggest their synergistic role in improving dietary quality. Sago grub products contribute energy and beneficial lipids, particularly unsaturated fatty acids with balanced ω6:ω3 ratios, while tilapia products supply high-quality protein and essential amino acids. Together, these products provide a nutritionally complementary profile that can help address both protein and energy gaps in local diets. This combination is particularly relevant in Papua, where access to diverse protein sources may be limited. MSME-based processing into nuggets and meatballs preserved nutritional integrity while enhancing consumer acceptability, shelf-life, and economic potential. Such value-added processing supports local food systems and empowers community-based enterprises.

Globally, edible insects are increasingly recognized as sustainable protein sources due to their high feed efficiency and low environmental impact (2,3,5). At the same time, fish and aquatic foods remain critical for nutrition security and dietary quality, especially in resource-limited settings (4). Therefore, integrating sago grub– and tilapia-based products into community nutrition programs could simultaneously advance health outcomes and sustainability goals, aligning with global recommendations for food security and environmentally friendly diets (1).

Despite these valuable findings, this study has several limitations. The descriptive design without inferential statistical testing limits the ability to draw definitive comparative conclusions. Replication was performed for proximate and fatty acid analyses; however, amino acid composition was determined from a single laboratory measurement due to resource limitations. Consequently, variability could not be estimated for the amino acid data, and these results should be interpreted with caution. Future research should include replicated analyses to strengthen data robustness and allow inferential comparisons. In addition, the analyses were restricted to macronutrient composition, selected fatty acids, and essential amino acids, with amino acid analysis conducted only once; therefore, variability could not be assessed. The study was also limited to MSMEs-processed products from a single village, which constrains the generalizability of the results.

Future research should expand the scope to include micronutrient bioavailability, food safety parameters, consumer acceptance, and economic feasibility. Longitudinal studies are needed to evaluate the nutritional impacts of regular consumption of these products, particularly in nutritionally vulnerable groups such as children and pregnant women. Broader investigations across different regions and production settings would also strengthen the evidence base for integrating sago grub– and smoked tilapia–based products into community nutrition and food security strategies.

CONCLUSION AND RECOMMENDATION

The findings suggest that processed sago grub and smoked tilapia based products may serve as promising local protein sources for dietary diversification in Papua. Sago grub products provide higher energy density and beneficial lipid profiles, while tilapia products offer superior protein levels and essential amino acid content. These complementary characteristics highlight their role in dietary diversification and food security strategies in Papua. At the same time, community-based processing into nuggets and meatballs ensures nutritional integrity, consumer acceptability, and economic value.

Further research is recommended to assess micronutrient bioavailability, food safety, consumer acceptance, and economic feasibility. Longitudinal studies are also needed to evaluate the long-term nutritional impacts of regular consumption, particularly among nutritionally vulnerable groups such as children and pregnant women.

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