Nutritional composition and sensory properties of snack bars made from sago worm paste (*Rhynchophorus ferrugineus*) as an alternative food

Meda Canti[1*], and *Shinta* Muliawan[1]

[1]Food Technology Study Program, School of Bioscience, Technology, and Innovation, Atma Jaya Catholic University of Indonesia, 15345 Tangerang, Indonesia

Abstract. Sago worms are a sustainable and nutritious food ingredient that requires further development to increase its wider utilization. This study aimed to develop snack bars made from sago worm paste and evaluate their proximate and sensory properties. The research stages included the preparation of sago worm paste and snack bars, followed by proximate and sensory analysis of the snack bars. Four formulas were used for the ratio of sago worm paste to wheat flour: 0:100 (F0), 25:75 (F1), 50:50 (F2), and 75:25 (F3). The ash, protein, lipid content, and total energy of the sago worm paste snack bars increased, while the acceptance scores for taste and aftertaste decreased. All snack bars were evaluated in accordance with the United States Department of Agriculture (USDA) standards. Additionally, the panellists accepted all snack bar treatments based on color, aroma, taste, aftertaste, texture, and overall acceptance. Formula F2 was found to be the best based on its nutritional composition and sensory properties.

1 Introduction

The world population reached 8.1 billion in 2023 and is projected to grow to 8.5 billion by 2030, 9.7 billion by 2050, and 10.4 billion by 2100 [1]. This population growth could lead to various negative impacts, including unsustainable harvesting practices such as animal exploitation, increased greenhouse gas emissions, and detrimental effects on both human health and the environment. Additionally, global demand for animal proteins continues to rise, which may lead to reduced land availability for food production. Increased livestock production contributes to climate change by raising temperatures, elevating carbon dioxide concentrations, altering precipitation patterns, and causing more frequent extreme weather events [2]. As a result, there has been a growing interest in exploring alternative, sustainable food sources.

Insects represent a sustainable food source because, compared to traditional livestock, they require less feed, land, and water, and produce fewer greenhouse gases and waste [3]. Despite being commonly regarded as pests, insects are underutilized in primary food

* Corresponding author: meda.canti@atmajaya.ac.id

production. Over 2,000 insect species have been deemed safe for human consumption by the World Health Organization (WHO) [4]. According to Borges et al. [5], the most widely consumed insect species worldwide include beetles and caterpillars (49%), followed by bees, wasps, and ants (14%), grasshoppers and crickets (13%), Hemiptera (10%), dragonflies (3%), termites (3%), flies (2%), and other orders (5%). Insects are rich in essential nutrients, including proteins, fibers, lipids, and minerals [6]. In addition, insects contain bioactive compounds, such as phenolic and flavonoid compounds, which function as antioxidants, anti-inflammatory agents, anticancer substances, antimicrobial and antibacterial agents, pancreatic lipase enzyme inhibitors, insulin regulators, and glycemic inhibitors [7]. These bioactive compounds highlight the potential of insects to serve as functional ingredients in food formulations. Various studies on the development of insect-based food products have been conducted, including nut bars made from buffalo worms (*Alphitobius diaperinus* P.) [8], burger patties from black soldier fly larvae [9], cookies made from cricket powder [10], meat analogues from grasshoppers [11], and bread made from mealworm powder (*Tenebrio molitor* L.) [12].

One insect with high nutritional value is the sago worm (*Rhynchophorus ferrugineus*). The nutritional composition of sago worms includes 53.1–60.2% moisture, 4.3–8.1% db ash, 11.3–13.4% db protein, 2–21% db lipid, and 62.2–78.6% db carbohydrate content [13]. Previous studies have explored food products derived from sago worms, such as crackers [14], seasoning powder [15], isolated proteins [16], Thai fish cakes [17], and protein extracts [18]. Given the potential of sago worms and the limited processing of their products, there is a need to develop innovative food products based on them.

Snack bars are solid, convenient food products that are easy to consume. Additionally, they serve as a quick source of nutrition, making them popular among consumers. Food innovations, such as snack bars made from sago worm paste, have not been explored before. The aim of this study was to develop snack bars using sago worm paste and evaluate their proximate composition and sensory properties.

2 Materials and methods

Fresh sago worms (*R. ferrugineus*), aged 30-40 days, were collected from Witherbal33 farmers in West Bandung District, Indonesia. Wheat flour (Kunci Biru), tapioca flour (Rose Brand), margarine (Blue Band), baking powder (Koepoe-Koepoe), egg yolk, sugar, and salt were sourced from the local market in Tangerang, Indonesia. All analytical-grade reagents were obtained from Sigma-Aldrich (Merck, Germany) and Behr Labor-Technik GmbH (Besha Analitika, Indonesia).

The procedure for preparing sago worm paste was carried out as described by Hurtado-Ribeira et al. [19]. First, the sago worms were thoroughly washed with cold water (4°C). Next, they were slaughtered by freezing at -18°C for 24 hours using a freezer (GEA AB-600TX, Indonesia). After freezing, the worms were dried in an oven (Elos Heat 55N, Germany) at 65°C for 24 hours. Finally, the dried sago worms were ground into a smooth paste using a food processor (Philip HR 2116, China).

The snack bars were prepared using the method outlined by Olagunju et al. [20]. Four different formulas were used for the ratio of sago worm paste to wheat flour in the preparation of snack bars: F0 (0:100), F1 (25:75), F2 (50:50), and F3 (75:25). This study employed a completely randomized design with two replications. The first step involved mixing the sago worm paste and wheat flour according to the treatment, along with 25 g of tapioca flour, 357 g of margarine, 35 g of egg yolk, 50 g of sugar, 1 g of baking powder, and 2 g of salt. The mixture was blended using a mixer (Philip HR 1552/50, China) until smooth. Finally, the dough was moulded and baked in an oven (Oxone OX899-RC, Indonesia) at 120°C for 2 hours.

Proximate analysis of the fresh sago worm, sago worm paste, and snack bars was conducted using the AOAC method [21]. The proximate composition includes moisture, ash, protein, lipid, and carbohydrate content. Total carbohydrate was calculated by subtracting the sum of moisture, ash, protein, and lipid content from 100%. The total energy of the snack bars was determined using the Atwater conversion factors: 4 kcal/g for protein, 9 kcal/g for lipid, and 4 kcal/g for carbohydrate. The proximate analysis results of the snack bars were then compared to USDA standards.

Sensory analysis was performed using a hedonic test with 40 semi-trained panellists [22]. The sensory attributes evaluated included colour, aroma, flavour, aftertaste, texture, and overall acceptability. A 1 to 7 scale was used for assessment, with the following criteria: 1 (dislike very much), 2 (dislike moderately), 3 (dislike slightly), 4 (neither like nor dislike), 5 (like slightly), 6 (like moderately), and 7 (like very much). The criteria for selecting the formula were an assessment score ranging from 4 to 7. All samples were presented randomly and anonymously. Prior to tasting each sample, panellists were asked to drink water and eat unsalted crackers to cleanse their palates. This study received ethical approval from the Ethics Development Center, Atma Jaya Catholic University of Indonesia (0008E/III/PPPE.PM.10.05/09/2023). Written informed consent was obtained from all participants.

Statistical analyses were conducted using IBM SPSS version 25.0. Data were analyzed using ANOVA, followed by Duncan's test (p<0.05). The results are presented as the mean ± standard deviation.

3 Results and discussion

As shown in Table 1, the moisture, ash, protein, lipid, carbohydrate content, and total energy of fresh sago worms were significantly different from those of sago worm paste (p<0.05). Fresh sago worms exhibited lower moisture, protein, and lipid contents compared to the values reported by Chinarak et al. [23], which indicated moisture content ranging from 64.9% to 67.9%, protein content between 18% db and 28.5% db, and lipids ranging from 52.4% to 60.1% db. Additionally, the ash, protein, and total energy content of fresh sago worms in this study were lower compared to those of African palm weevil larvae, which had ash content ranging from 2.03% to 2.75% db, protein content from 24.24% to 27.53% db, and total energy ranging from 802 to 1190 kcal/100 g [24]. The differences in approximate composition are likely influenced by factors such as the metamorphosis stage, the origin of the insect, and its diet [25].

Table 1. Nutritional composition of fresh sago worm, sago worm paste, and snack bars

Properties	Fresh sago worm	Sago worm paste	F0	F1	F2	F3
Moisture (%)	54.58±0.06^{a}	4.54±0.12^{d}	7.52±0.60^{b}	7.95±0.08^{b}	7.90±0.08^{b}	6.46±0.09^{c}
Ash (%db)	2.26±0.02^{b}	2.52±0.01^{a}	1.16±0.01^{f}	1.59±0.02^{e}	1.70±0.02^{d}	1.89±0.01^{c}
Protein (%db)	25.36±0.50^{a}	24.14±0.57^{b}	8.89±0.13^{f}	10.56±0.26^{e}	12.32±0.33^{d}	14.08±0.27^{c}
Lipid (%db)	48.59±0.62^{b}	60.40±0.69^{a}	18.04±0.52^{f}	27.63±0.16^{e}	30.66±0.88^{d}	34.04±0.52^{c}
Carbohydrates (%db)	23.79±0.11^{e}	12.94±0.10^{f}	71.91±0.66^{a}	60.22±0.40^{b}	55.32±0.53^{c}	46.99±0.23^{d}
Total energy (Kcal/100 g)	292±1.81^{f}	661±2.50^{a}	451±2.68^{e}	490±1.21^{d}	504±4.51^{c}	527±3.00^{b}

Note: Values are given as mean ± standard deviation (SD) based on two replicate determinations. Different letters in the same row indicate significant differences (P <0.05). %db (dry basis). The ratio of sago worm pastes and wheat flour is F0 (0:100), F1 (25:75), F2 (50:50), and F3 (75:25).

Based on Table 1, the protein content of sago worm paste was 24.14% db. This protein content is higher than that found in other animal protein sources, such as beef (22.5%), pork (21.3%), chicken (22.2%), and salmon (22.2%) [26]. This suggests that sago worm paste could serve as an alternative protein source. Additionally, sago worm paste had a high lipid content of 60.40% db. Kouřimská and Adámková [25] reported that edible insects typically have lipid content ranging from 10% to 60%. In insects, lipids serve as energy reserves and are primarily present as triacylglycerols and phospholipids. Sago worm paste had higher moisture and lipid content, as well as greater total energy, compared to sago worm flour reported by Ariani et al. [27] (moisture content: 1%, lipid: 18.27% db, and total energy: 333 kcal/100 g). However, the ash, protein, and carbohydrate contents of sago worm paste were lower than those of sago worm flour (ash: 2.66% db, protein: 34.02% db, and carbohydrate: 45.05% db). Differences in nutritional content can be attributed to variations in preparation and processing methods, such as pasting, drying, cooking, and frying [25].

The nutritional composition of the snack bar, including ash, protein, lipid, and total energy content, increased significantly with the addition of sago worm paste ($p<0.05$), as sago worm paste has a high nutritional content (Table 1). The addition of sago worm pastes to snack bars resulted in a higher protein content than standard nut bars (10.78%) and nut bars with yellow mealworm flour (13.11%) [8]. Compared to USDA standards, the nutritional content (protein, lipid, and total energy) of snack bars made from sago worm paste met the required criteria [28]. The protein, lipid, and carbohydrate content of F3 was higher than that of commercial snack bars (*Essento*) made from cricket powder (*Acheta domesticus*) (protein content: 13%; lipid: 22%; and carbohydrate: 26%) [29]. Additionally, moisture and carbohydrate content decreased with the addition of sago worm paste. This is because the cooking process can trigger a series of complex reactions, including denaturation, gelatinization, oxidation, hydrolysis, isomerization, and polymerization, all of which affect the nutritional composition of food products [30].

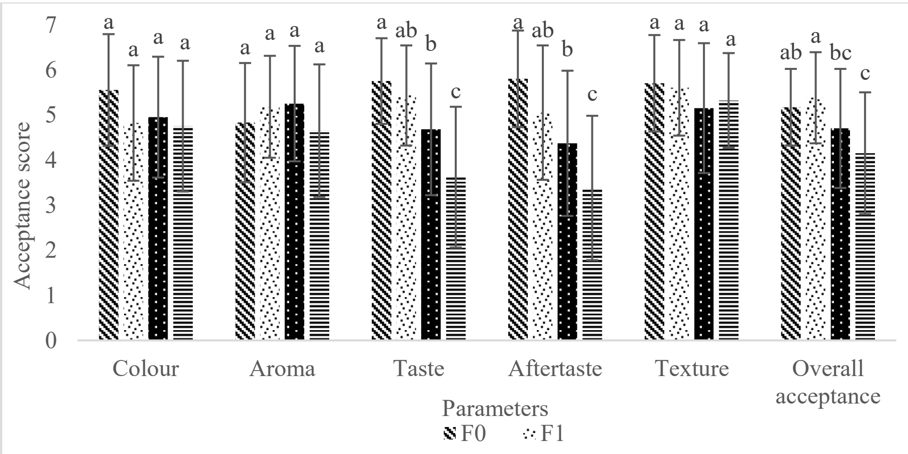
The visual appearance of the snack bars made from sago worm paste is shown in Fig. 1. The formula with a higher proportion of sago worm paste resulted in a darker color. As the amount of sago worm paste increased, the lightness value decreased. This can be attributed to both enzymatic and non-enzymatic browning processes during the preparation of sago worm paste and the baking of the snack bars.

F0 F1 F2 F3

Fig. 1. Snack bars made from sago worm paste. The ratio of sago worm pastes and wheat flour is F0 (0:100), F1 (25:75), F2 (50:50), and F3 (75:25).

Based on the acceptance scores of developed snack bars, the addition of sago worm paste significantly affected their taste and aftertaste ($p<0.05$) (Fig. 2). The F3 formula had a taste and aftertaste that panellists slightly disliked, likely due to the amino acid content of the sago worm. Chinarak et al. [23] reported that sago worm paste contains a high glutamic acid content (2.5–7.0 g/100 g dry sample), which could contribute to an umami flavor. In addition, sago worms contain the amino acid tryptophan, which contributes to their bitter taste [31]. However, the panellists accepted all the snack bars for all sensory attributes. Kowalski et al.

[8] reported that adding edible insect powder to nut bars up to 30% was acceptable to panellists. F2 was identified as the best treatment due to its favorable proximate composition and sensory properties, making it suitable for commercial production.



Note: Hedonic scale: 1 (dislike very much), 2 (dislike moderately), 3 (dislike slightly), 4 (neither like nor dislike), 5 (like slightly), 6 (like moderately), and 7 (like very much). The ratio of sago worm pastes and wheat flour is F0 (0:100), F1 (25:75), F2 (50:50), and F3 (75:25).

Fig. 2. Acceptance score of developed snack bars made from sago worm paste (n = 40).

4 Conclusion

The findings of this study successfully led to the development of a snack bar made from sago worm paste, which can serve as an alternative food source. The addition of sago worm paste significantly impacted the snack bar's ash, protein, lipid, and total energy content. The nutritional composition of the snack bar meets USDA standards, with F3 exhibiting a higher protein content than commercial snack bars. The protein content of snack bars containing 75% sago worm paste was higher than that of commercial snack bars. Panellists accepted all sensory parameters of the snack bars, with the treatment containing 50% sago worm paste (F2) being the most favorable. This study successfully developed a snack bar made from sago worm paste as an alternative food source. All snack bar treatments met USDA nutritional standards and exhibited sensory characteristics that were acceptable to the panellists. The best snack bar treatment, based on both nutritional content and sensory attributes, was F2.

This study successfully developed a snack bar made from sago worm paste, with nutritional content meeting USDA standards. Based on sensory evaluation, all the snack bar formulations were well-accepted by the panellists. The F2 formulation emerged as the best option and shows potential as an alternative food source.

Acknowledgements

The authors extend their sincere gratitude to School of Bioscience, Technology, and Innovation, Atma Jaya Catholic University of Indonesia, for their invaluable support throughout the research process.

References

1. United Nations. Populations. Available from: https://www.un.org/en/global-issues/population. (2022)
2. M. Cheng, B. McCarl, C. Fei, Climate change and livestock production: a literature review. Atmosphere. **13**, 140 (2022). https://doi.org/10.3390/atmos13010140
3. C. Fu, W.A. Cheema, M. Mobashar, A.A. Shah, M.M. Alqahtani, Insect as sustainable feed: enhancing animal nutrition and reducing livestock environmental impression. J. Animal Physiology and Animal Nutrition. **1**, 1–11 (2024). https://doi.org/10.1111/jpn.14055
4. A. Conway, S. Jaiswal, A.K. Jaiswal, The potential of edible insect as a safe, palatable, and sustainable food source in the European Union. Foods. **13**, 387 (2024). https://doi.org/10.3390/foods13030387
5. M.M. Borges, D.V. da Costa, F.M. Trombete, A.K.F.I. Câmara, Edible insects as a sustainable alternative to food products: an insight into quality aspects of reformulated bakery and meat products. Current Opinion in Food Science. **46**, 100864 (2022). https://doi.org/10.1016/j.cofs.2022.100864
6. A.A. Shah, P. Totakul, M. Matra, A. Cherdthong, Y. Hanboonsong, M. Wanapat, Nutritional composition of various insects and potential uses as alternative protein sources in animal diets. Anim. Biosci. **35**, 317–331 (2022). https://doi.org/10.5713/ab.21.0447
7. D. Aiello, M. Barbera, D. Bongiorno, M. Cammarata, V. Censi, S. Indelicato, F. Mazzotti, A. Napoli, D. Piazzese, F. Saiano, Edible insects an alternative nutritional source of bioactive compounds: a review. Molecules. **28**, 699 (2023). https://doi.org/10.3390/molecules28020699
8. S. Kowalski, J. Oracz, M. Skotnicka, A. Mikulec, D. Gumul, B. Mickowska, A. Mazurek, R. Sabat, A. Wywrocka-Gurgul, D. Zy˙zelewicz, Chemical composition, nutritional value, and acceptance of nut bars with the addition of edible insect powder. Molecules. **27**, 8472 (2022). https://doi.org/10.3390/molecules27238472
9. L.W. Bessa, E. Pieterse, J. Marais, L.C. Hoffman, Black soldier fly larvae (*Hermetia illucens*) as a meat replacer in a burger patty. J. Insect as Food and Feed. **9**, 1211–1222. https://doi.org/10.3920/JIFF2021.0208
10. F. Ayustaningwarno, A.M. Ayu, L. Syiffah, H. Muthia, F.A. Amalina, D.N. Afifah, Y. Nindita, N. Maharani, N. Widyastuti, G. Anjani, D.M. Kurniawati, N. Rustanti, M.T. Susilo, E.R. Noer, A. Rizqiawan, Physicochemical and sensory properties of cookies with cricket powder as an alternative snack to prevents iron deficiency anemia and chronic energy deficiency. Applied Food Research. **4**, 100495. https://doi.org/10.1016/j.afres.2024.100485
11. N.S. Priyatnasari, E. Palupi, F. Kamila, K.R. Ardhiani, Khalisah, G.T. Prilyadi, A.C. Iwansyah, Meat-analog made from Javanese Grasshopper, kidney beans, and elephant foot yam as a high-protein and low-cholesterol product. J. Agriculture and Food Research. **16**, 101071 (2024). https://doi.org/10.1016/j.jafr.2024.101071
12. S. Pyo, C. Moon, S. Park, J. Choi, J. Park, J.M. Sung, E. Choi, Y. Son, Quality and staling characteristics of white bread fortified with lysozyme-hydrolyzed mealworm powder (*Tenebrio molitor* L.). Current Research in Food Science. **8**, 100685 (2024). https://doi.org/10.1016/j.crfs.2024.100685
13. A. Promwee, K. Chinarak, W. Panpipat, A. Panya, N. Phonsatta, M. Harcet, M. Chaijan, Balancing the growth performance and nutritional value of edible farm-raised sago palm

weevil (*Rhynchophorus ferregineus*) larvae by feeding various plant supplemented-sago palm trunk diets. Foods. **12**, 3474 (2023). https://doi.org/10.3390/foods12183474

14. H.C.D. Tuhumury, A. Souripet, S.J. Nendissa, Effects of sago starch types on crackers from edible larvae of sago palm weevils. Indonesia Food Science and Technology Journal. **4**, 1–5 (2020). https://doi.org/10.22437/ifstj.v4i1.10305
15. M. Chaijan, W. Panpipat, Techno-biofunctional aspect of seasoning powder from farm-raised sago palm weevil (*Rhynchophorus ferrugineus*) larvae. J. Insect as Food and Feed. **7**, 187–195 (2021). https://doi.org/10.3920/JIFF2020.0025
16. M. Chaijan, K. Chumthong, N. Kongchoosi, K. Chinarak, A. Panya, N. Phonsatta, L.Z. Cheong, W. Panpipat, Characterisation of pH-shift-produced protein isolates from sago palm weevil (*Rhynchophorus ferrugineus*) larvae. J. Insect as Food and Feed. **8**, 313–324 (2022). https://doi.org/10.3920/JIFF2021.0085
17. P. Kingwascharapong, K. Petsong, S. Karnjanapratum, J. Pongsetkul, Development and characterization of Thai Fish Cake (Tod Mun Pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*). Current Applied Science and Technology. **22**, 1–18 (2022). https://doi.org/10.55003/cast.2022.06.22.011
18. R. R. Kavle, E.T.M. Pritchard, A. Carne, A.E.A. Bekhit, J.D. Morton, D. Agyei, Nutritional composition and techno-functional properties of sago palm weevil (*Rhynchophorus ferrugineus*) larvae protein extract. J. Asia-Pacific Entomology. **26**, 102086 (2023). https://doi.org/10.1016/j.aspen.2023.102086
19. R. Hurtado-Riberia, D. Villanueva-Bermejo, M.R. García-Risco, M.D. Hernández, M.J. Sánchez-Muros, T. Fornari, L. Vázquez, D. Martin, Evaluation of the interrelated effects of slaughtering, drying, and defatting methods on the composition and properties of black soldier fly (*Hermetia illucens*) larvae fat. Current Research in Food Science. **7**, 100633 (2023). https://doi.org/10.1016/j.crfs.2023.100633
20. A.I. Olagunju, T.I. Arigbede, S.A. Makanjuola, E.T. Oyebode, Nutritional compositions, bioactive properties, and *in-vivo* glycemic indices of amaranth-based optimized multigrain snack bar products. Measurement: Food. **7**, 100039 (2022). https://doi.org/10.1016/j.meafoo.2022.100039
21. Association of Official Analytical Chemists (AOAC), Official Methods of Analysis of AOAC International, twenty first ed. (AOAC International, Washington, DC, USA, 2019)
22. S.H. Lim, N.L. Chin, A. Sulaiman, C.H. Tay, T.H. Wong, Sensory analysis for cow milk product development using high pressure processing (HPP) in the dairy industry. Foods. **11**, 1233 (2022). https://doi.org/10.3390/foods11091233
23. K. Chinarak, M. Chaijan, W. Panpipat, Farm-raised sago palm weevil (*Rhynchophorus ferrugineus*) larvae: potential and challenges for promising source of nutrients. J. Food Composition and Analysis. **92**, 103542 (2020). https://doi.org/10.1016/j.jfca.2020.103542
24. A.R.F. Mba, G. Kansci, M. Viau, L. Ribourg, J.F. Muafor, N. Hafnaoui, P. Le Gall, C. Genot, Growing conditions and morphotypes of African palm weevil (*Rhynchophorus phoenicis*) larvae influence their lipophilic nutrient but not their amino acid compositions. J. Food Composition and Analysis. **69**, 87–97 (2018). https://doi.org/10.1016/j.jfca.2018.02.012
25. L. Kouřimská, A. Adámková, Nutritional and sensory quality of edible insects. NFS Journal. **4**, 22–26 (2016). https://doi.org/10.1016/j.nfs.2016.07.001
26. A.M. Liceaga, Edible insects, a valuable protein source from ancient to modern times. Adv. Food Nutr. Res. **101**, 129–152 (2022). https://doi.org/10.1016/bs.afnr.2022.04.002

27. Ariani, G. Anjani, M.A.S. Adji, K. Djamiatun, Tepung ulat sagu (*Rhyinchophorus ferrugineus*) imunomodulator Nitric Oxide (NO) sirkulasi mencit terapi antimalaria standar. The Indonesian J. Nutrition. **6**, 131–138 (2018). https://doi.org/10.14710/jgi.6.2.131-138
28. United States Departement of Agriculture (USDA). FoodData Central, Formulated bar, Mars Snackfood US, Cocoavia, Chocolate Almond Snack Bar. Available from: https://fdc.nal.usda.gov/fdc-app.html#/food-details/174782/nutrients (2019)
29. Essento. Nutritional values of essento insect protein bar. Available from: https://essento.food/en/products/raw-cacao-protein-bar (2024)
30. D. Oppong, W. Panpipat, L. Cheong, M. Chaijan, Comparative effect of frying and baking on chemical, physical, and microbiological characteristics of frozen fish nuggets. Foods. **10**, 3158 (2021). https://doi.org/10.3390/foods10123158
31. A.A. Bachmanov, N.P. Bosak, J.I. Glendinning, M. Inoue, X. Li, S. Manita, S.A. McCaughey, Y. Murata, D.R. Reed, M.G. Tordoff, G.K. Beauchamp, Genetics of amino acid taste and appetite. Adv. Nutr. **7**, 806S–822S (2016). https://doi.org/10.3945/an.115.011270