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Valorisation of Fish Bones and Scales in Production of Nutritionally Enriched Cookies: A Sustainable Approach to Child Nutrition

Besinsel Değeri Yüksek Kurabiye Üretimi için Balık Kemiği ve Pullarının Kullanımı: Çocuk Beslenmesi için Sürdürülebilir Bir Yaklaşım

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Abstract

Objective: The aim of this study is to valorise fish bones and scales in a cookie recipe to increase fish consumption of children and reevaluate wasted fish by-products. Thus, this culinary application tested whether a value-added, protein-rich ingredient can be used to prepare cookies for children and also serve sustainable gastronomy and sustainable development goals in the context of zero hunger, good health and well-being, responsible consumption and production and life below water.

Material and method: Two different types of cookies were produced by using fish scales and bones. Scales and bones of just one fish species, namely sea bass, was used in the recipes.

Results: Fishy odor could not be eliminated when both bones and scales were added; yet, no odor was detected when only scales were used.

Conclusion: This research demonstrates how fish scales can be used as a functional ingredient to improve the nutritional profile of baked goods without degrading their sensory qualities. By turning what is usually considered waste into a useful, edible resource, the study also highlights the significance of circular food systems. In this sense, the study helps to promote sustainable food innovation practices and lessen food waste. To increase product acceptability and broaden applications, future research could look into odor-reduction techniques, different flavour masking, or the addition of different fish species.

Özet

Amaç: Bu çalışmanın amacı çocukların balık tüketimini artırmak amacıyla kurabiye tarifinde balık kılçığı ve pullarının değerlendirilmesi ve israf edilen balık yan ürünlerinin yeniden değerlendirilmesidir. Böylece, bu mutfak uygulaması, besin değeri ve protein açısından zengin bir bileşenin çocuklara yönelik kurabiye hazırlamak için kullanılıp kullanılamayacağını test ederken, aynı zamanda sürdürülebilir gastronomi ve sürdürülebilir kalkınma hedeflerinden sıfır açlık, iyi sağlık ve refah, sorumlu tüketim ve üretim ile su altında yaşama da katkı sağlamak amacını taşımaktadır.

Gereç ve Yöntem: Balık pulları ve kemikleri kullanılarak iki farklı kurabiye çeşidi üretilmiştir. Tariflerde tek bir balık türü olarak levrek pulları ve kılçıkları kullanılmıştır.

Bulgular: Hem kemik, hem de pul eklenerek hazırlanan kurabiyelerde balık kokusu tam olarak giderilemezken; sadece pul kullanılarak hazırlanan kurabiyelerde herhangi bir koku tespit edilmemiştir.

Sonuç: Bu araştırma, balık pullarının duyusal özelliklerini bozmadan fırınlanmış ürünlerin besin profilini iyileştirmek için nasıl işlevsel bir bileşen olarak kullanılabileceğini göstermektedir. Çalışma, genellikle atık olarak kabul edilen şeyi faydalı, yenilebilir bir kaynağa dönüştürerek döngüsel gıda sistemlerinin önemini de vurgulamaktadır. Bu anlamda, çalışma sürdürülebilir gıda inovasyonu uygulamalarını teşvik etmeye ve gıda israfını azaltmaya yardımcı olmaktadır. Ürünün kabul edilebilirliğini artırmak ve uygulamaları genişletmek için gelecekteki araştırmalar koku azaltma tekniklerini, farklı tat maskeleme yöntemlerini veya farklı balık türlerini inceleyebilir.

Introduction

The importance of sustainability and zero waste has been strongly emphasized in the last century due to serious global crisis (1,2). The world's resources are faced with extinction because of excessive and unconscious use by human beings; overfishing; pollution and climate change being the most prominent ones for marine ecosystem. Sustainable practices can help the improvement of world ecosystem in many ways (3-5). Ocean or sea water has an important role and impact on the overall health and sustainable development of the planet. It supports all life by producing oxygen, absorbing carbon dioxide, recycling nutrients, and regulating global climate and temperature. As a source of food and livelihood for a significant part of the global population, as well as the tourism industries, the oceans have the potential to achieve the major sustainable goals of eliminating hunger and poverty (6). One of the ways to support sustainability with zero waste goal is to utilize marine by-products that is treated as waste.

By considering the relationship between sustainable gastronomy and the protection of marine ecosystem, this study aims to contribute to how a sustainable culinary application can be built by using fish waste by-products, scales and bones in current study, in a recipe development.

Türkiye is a peninsula with seas on three sides. Although the seas are rich in fish varieties, its consumption is much lower when compared to other countries. There are multiple reasons of this situation; financial impossibilities, eating habits, education, regional differences etc. (7,8).

According to authorities in nutritional science, fish has an important contribution to human development, both mentally and physically; thus, they emphasize the importance of consuming fish regularly, especially during childhood (9-11). Fish is of high nutritional value when taken as a whole but most of the time bones and scales are often thrown away. These two parts of the fish become edible using different techniques. Despite cold chain practices, only 50-60% of the fish can be consumed; it is possible to increase this rate to 90% with different culinary applications (12).

There is a need for integrating aquaculture waste with gastronomy and culinary arts to valorize wasted resources while heightening their nutritional and flavourful potential. Utilizing aquaculture waste to create culinary delights would be an example for using resources more sustainably while introducing new gastronomic experiences (13). Thus, it is aimed to make cookies by using fish scales and bones to develop a healthy snack for children that contains fish. The ultimate goal is to create a cookie rich in nutritional value that can be consumed by those children who refuse to eat fish but love cookie type snacks. Such a cookie trial can also be a good example for sustainable gastronomy practices as well.

Fish is a food with high nutritional value and has numerous significant positive effects on health. Fish is well-known for being a high-quality protein source. Protein is necessary for immune system support, muscle growth, and tissue repair. It also includes a variety of nutrients, including minerals as zinc, selenium, and iodine and vitamins as D, B12, and A. Regular fish eating can also lower inflammation, enhance mood, maintain eye health, and even lower the incidence of type 2 diabetes (14). Omega-3 fatty acids can enhance cognitive performance and lower the risk of cognitive impairment linked to aging. They are essential for brain growth and function. Fish, which is particularly high in omega-3 fatty acids, has anti-inflammatory properties, dilates blood vessels, lowers blood pressure, and promotes heart health (15). The highest concentration of n-3 polyunsaturated fatty acids may be found in fish and seafood. It has been observed that polyunsaturated fatty acids, namely EPA and DHA derived from fish oil, are highly effective in lowering the risk of heart attacks, strokes, hypertension, cardiac arrhythmias, diabetes, rheumatoid arthritis, depression, cancer, and brain development (16-18). One of the most prevalent minerals in the human body is calcium. It combines biomolecules to generate a wide range of complex compounds, particularly with the proteins that build cartilage and bones. Fish, particularly the little native species, are excellent providers of calcium. Among the fish that are rich in calcium are the tiny native species. All of the soft bones from this fish are consumed intact and can be a great source of calcium (19, 20).

Fish constitutes an important part of the dietary recommendations for children with malnutrition, and is a food that can be safely consumed by growing children, pregnant and lactating women, those with cardiovascular diseases and those who should not consume red meat (21). Children who have malnutrition may end up with serious short-term as delayed cognitive development, medium-term as worse school accomplishment, and long-term as non-communicable chronic illnesses problems. Fish has been recognized as an important source of high quality animal protein required for bodybuilding and other physiological functions in children compared to adults. Besides, during childhood stage, the provision of adequate protein intake is very crucial for the overall growth and development into adulthood. As fish is tender and easily digested than meat, its consumption in children would be an excellent source of calcium and fluorine essential for the development of strong bones and teeth (22). The regular function of tissues and the central nervous system, as well as the growth and mineralization of bones, depend on calcium. Additionally, it is important for blood clotting. The highest consumption of phosphorus, calcium, and fluorine occurs when young fish are eaten with their bones in (23).

There are some significant differences in fish and seafood consumption between countries; China ranking first with 57,474 million tons annually whereas Türkiye comes almost at the bottom of the list with 465 thousand tons. Although Türkiye has the advantage of access to fish and seafood, fish consumption is an average of 5.52 kg per person per year. However, these figures are below the world average, which shows that Türkiye needs to go a long way in aquatic products consumption (24). In the future, consumption of aquatic products is expected to increase as people are turning to healthier eating habits and that the contribution of the aquaculture industry to the global economy is increasing (25). As a result, seafood consumption will continue to increase both worldwide and in Türkiye. It is time for Türkiye to stand out in the aquaculture sector and play a greater role in global fish consumption. We should be aware that seafood is a nutritious and healthy nutrition option and direct our consumption habits accordingly (26).

Materials and Methods

The methodology adopted new product development stages; starting with idea generation, followed by idea screening, concept development and testing, and prototype product development, Yet; marketing strategy development, business analysis, test marketing and commercialization stages were eliminated as the main objective of the study was limited to exprimental product development rather than commercialization of the product. The systematic process for the product development can be summarized as follows:

• Idea Generation: literature review, observations of children's fish consumption, and parental feedback to identify the opportunity of incorporating fish by-products into snack foods.

• Idea Screening: a preliminary market scan for similar products and a short exploratory survey with parents to evaluate product acceptability.

• Concept Development and Testing: determination of product type as cookies based on children's high preference for sweet bakery items.

• Product Development: multiple trials using fish bones and scales in different ratios and processing methods to optimize recipe formulation.

While researchers' observations, fish consumption statistics and literature review were used to identify the need for incorporating fish by-products into children' snack at the idea generation stage; the market was scanned to find out whether similar products exist at the idea screening stage. Also, a short survey was conducted with parents to collect data about their children's fish consumption. Concept development and product testing stages included main product selection as cookie since it is one of children's favorite. Various techniques were practiced and trials were made to modify recipes.

Ethical Aspect of the Research

The study adhered to ethical guidelines, ensuring the confidentiality and anonymity of all participants. Informed consent was obtained from each participant prior to data collection. İzmir University of Economics Ethics Committee validated the study with their ethics approval, which was obtained on 26.07.2024 with the reference number B.30.2.İEÜ.0.05.05-020-384.

Results

Survey Results Related to Children Fish Consumption

To collect data about children's fish consumption habits, a short survey with six close-ended questions was created. The survey was administered online with 20 voluntary respondents; all of which were parenting children aged 5-12 years old in İzmir, Türkiye. Questions and their answers are indicated on Table 1 shown below:

The results indicated that children moderately liked fish; most children (55%) consumed fish only once or twice a month, whereas only 35% consumed it weekly. 70% of parents believed their children consumed fish in insufficicent amounts and they would prefer they consumed more. Lastly, they expressed their willingness to feed their children with fish by-product cookies and their children's interest in cookies in general. These survey results supported children's low consumption of fish as well as fish by-product cookies' potential acceptability.

Product Development

Fresh sea bass scales and bones were obtained from a local supplier at the fish bazaar in Kaynaklar district of Buca, İzmir. Bones and scales went through separate treatments as shown in Table 2. The main objective was to dehydrate and powder both products.

First, the scales were demineralized with lactic acid and sodium chloride and then they were dehydrated. Next, bones were boiled and separated from proteins and unwanted substances, then they were dried and powdered.

The scales were washed with a solution prepared with sodium chloride (NaCl) (non-iodized industrial salt) and water at a ratio of 10% of the scale weight and filtered. The scales were kept at 4°C for 24 hours with the solution prepared using the same ratio. The solution was refreshed every 12 hours. At the end of 24 hours, the scales were drained and washed with water. Then washed with distilled mineral water and rinsed. After that, scales were treated in lactic acid solution with a 1:10 (w/w) ratio at room temperature for 3 hours. The scales were then washed with mineral-free water until the pH value was neutral. And lastly, scales were dehydrated at 60-65°C for 72 hours. The process is shown in Figure 1:

Fish bones were also treated as depicted in Figure 2. After placing the sea bass bones in a pot, water was added to cover them. It was boiled for 30 minutes until the bones were cooked and drained. The protein, blood and unwanted particles were separated from the bones. The bones were broken at the joints so that they could dehydrate evenly.

The oven and solar drying techniques used in the first trial deteriorated the smell of the bones. The second drying process was done using a dehydration machine. It was dried for 72 hours at 60-65°C and powdered using a spice grinder.

The scales could not be converted into powder form effectively due to their flexible structure. Instead, they were fried in olive oil until crisp. Flour, brown sugar, granulated sugar, dark

Table 1. Children's fish consumption

Questions	Options	f	%	n
Does your child like fish?	Not at all	3	15%	20
	Slightly	5	25%	
	Moderately	6	30%	
	Very	3	15%	
	Extremely	3	15%	
How often does your child consume fish?	1-2 times a month	11	55%	20
	1-2 times a week	7	35%	
	2-3 times a month	2	10%	
Do you think your child is consuming enough fish?	yes	6	30%	20
	no	14	70%	
Would you like your child to consume more fish?	yes	18	90%	20
	no	2	10%	
Does your child like to eat cookies?	yes	17	85%	20
	no	3	15%	
Would you like to increase their fish consumption with a cookie made with fish bones and scales?	yes	16	80%	20
	no	4	20%	

chocolate, white chocolate and milk chocolate, eggs, baking powder, baking soda and fish scales were the main ingredients used to make the first trial. After all the products were mixed, they were baked at 180°C for 10 minutes in a convection oven. Recipe outcome is shown in Figure 3.

The study showed that while fish scales can be successfully added to cookies, fish bones need additional processing innovations such as finer milling or masking agents or addition of flavors such as cocoa, spices to enhance their sensory qualities.

Discussion and Conclusion

In order to increase children's consumption of fish, the current study investigated the viability of using fish scales and bones—which are usually thrown away as processing by-products—in cookies. The results offer a number of insights into the technological difficulties and nutritional potential of this kind of approach. According to the literature-based nutritional analysis, fish scales provide collagen peptides and proteins that may improve the health of the bones and skin, while fish bones are a great source of calcium, phosphorus, and collagen (27-30). Given that childhood calcium deficiency can result in long-term developmental issues, this finding is significant. According to earlier studies on the use of fish by-products, odor can be reduced by using sophisticated drying techniques, enzymatic hydrolysis, or the addition of flavor-masking ingredients like cocoa, spices, or strongly flavoured inclusions (15).

The Sustainable Development Goals (SDGs), especially Zero Hunger (SDG 2), Good Health and Well-Being (SDG 3), Responsible Consumption and Production (SDG 12), and Life Below Water (SDG 14), are directly impacted by the value-adding of fish byproducts. This study provides a tangible illustration of how sustainable gastronomy can promote environmental preservation and human health by turning low-value waste into nutrient-rich foods.

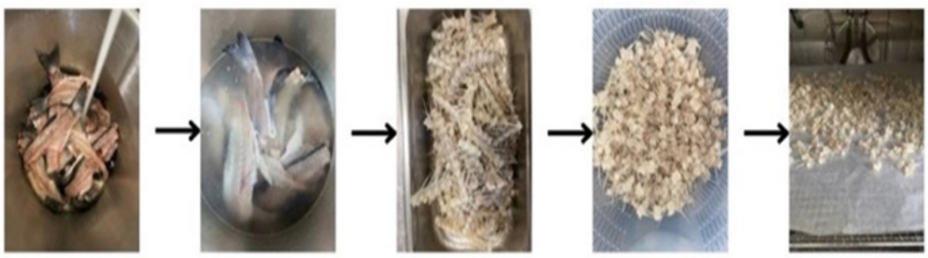
Table 2. Treatment of fish scales and bones

Fish by-product	Treatment	
scales	washing	rinsed in a 10% NaCl solution relative to their weight, kept at 4 °C for 24 hours, and the solution was refreshed every 12 hours
	demineralization	treated in lactic acid solution (1:10 w/w) for 3 hours at room temperature until neutral pH was reached after repeated washing with distilled water.
	drying	dehydrated at 60–65 °C for 72 hours.
	grinding/frying	fried in olive oil until crisp since grinding didn't work effectively
fish bones	washing	washed thoroughly under water
	boiling	boiled for 30 minutes until softened
	drying	oven dried and solar dried; yet, resulted in undesirable odors; a dehydration machine was employed at 60–65°C for 72 hours.
	grinding	ground using a spice grinder; however, particle size was coarser than expected

Figure 1. Fish scale dehydration process

relatively satisfied the expectations although it was developed in a commercial kitchen setting. Thus, the grinder used to grind the bones into flour did not yield the desired result; a finer flour, which was supposed to have a smoother texture. The fishy odor and taste from the bones could not be eliminated and the fishy odor continued to emanate from the cookie as well. Yet, the scales didn't give off undesirable odors Also, the grinder that was used could not shred the scales due to its flexible structure. Scales were first fried in olive oil to make them crispy and then they were added to the cookie. As a result, the first trial formula that was incorporated with only scales had an odorless and crispy texture. The second cookie made with fish bone and fish scales together had a fishy smell and a texture of hard crumbs. Therefore, future research

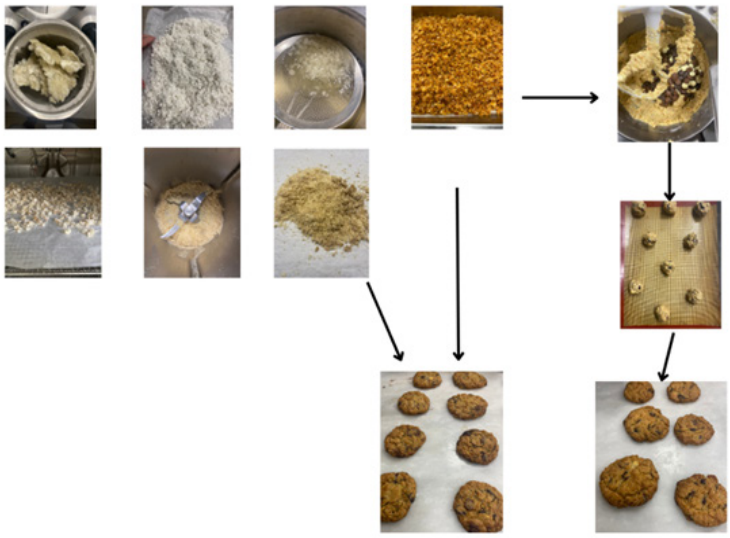
Figure 2. Fish bone dehydration process



should concentrate on improving formulation and processing technology to strike a balance between sensory acceptability and nutritional enrichment.

The idea of sustainability is now essential to every aspect of modern life. To guarantee the conservation and sustainable use of marine resources, especially in the Mediterranean region, a number of studies and initiatives are being carried out. In terms of fish production and capture fisheries, Türkiye is one of the top European nations, with steadily rising production

Figure 3. Cookie recipe development



In the second product trial, 1/4 of the flour that ground fish bones and the same amount of fish scales were added and the second cookie was formed with the same ingredients explained above. Formulas are summarized on Table 3

Table 3. Product trial formulas

	Texture	Aroma	Appearance	Acceptability
Formula A	produced a crispy texture	no detectable fish odor	no difference when compared to classic cookies	promising for further development
Standard cookie dough (wheat flour, brown sugar, granulated sugar, butter, eggs, baking powder, baking soda, mixed chocolate chips) supplemented with fried fish scales at 5% of flour weight.				
Formula B				
In addition to scales, ground fish bone powder was incorporated by substituting 25% of wheat flour with bone flour.	produced hard, coarse crumbs	persistent fishy odor	slightly different when compared to classic cookies	not acceptable at its actual form

volumes. However, despite their potential as a nutritional resource, a large percentage of fish by-products, such as bones and scales, are frequently discarded and remain underutilised. Emerging initiatives in recent years have aimed to encourage the recycling and value-adding of these byproducts.

Türkiye lags behind many other countries in terms of per capita fish consumption, despite its strong position in fish production. Despite the fact that fish is acknowledged as an essential dietary component that supports both physical and cognitive development during childhood, this disparity is especially noticeable among children, who consume less fish than adults.

In order to support the sustainability of marine ecosystems and promote creative gastronomic practices, the current study was created to assess fish by-products within the parameters of the zero-waste approach. Despite the established developmental benefits of fish, children were chosen as the main target group because of their relatively low levels of consumption. In order to achieve this, the study concentrated on using fish scales and bones, which are normally discarded, to create a cookie recipe that appeals to kids' palates. To evaluate their potential for producing a palatable and sustainable food product, seabass bones and scales were added to the recipe during the experimental phase.

The resulting cookie can be refined with collaborative studies with other related academic disciplines such as food engineering and aquaculture and fisheries. These collaborations could support validation of nutritional claims with laboratory analyses. A more detailed analysis of the nutrient composition of fish bones and scales would be particularly supporting to reveal the potential contributions of macronutrients that are critical for the growth and development of children. Sensory evaluations with children would help to determine which masking agents and flavors could be used to eliminate fish odor. Fish by-product cookies stand as an innovative approach towards sustainable gastronomy and child-friendly snack if the remaining challenges are resolved.

Author Contribution

MÖ: Data collection, investigation, formal analysis, and writing the original draft

FY: Research administration, supervision, conceptualization, methodology, review and editing

Conflicts of Interest

All authors declare that there are no conflicts of interest regarding the research.

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