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Using Edible Insects in Production of Cookies, Biscuits, and Crackers †

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Abstract: The world population is ever-increasing and thus, food security is becoming a big problem. To meet protein demand, edible insects could be a sustainable, eco-friendly, economical, and alternative source. However, consumers have some concerns about the sensorial properties of edible insect-based foods. To make them invisible and more familiar for consumers, powder of edible insects could be used together with flours in most commonly consumed bakery products, in particular bread followed by biscuits, cookies, and crackers. Moreover, the rearing and processing conditions should be enhanced, marketing strategy should be developed and education about health and environmental benefits should be given.

Keywords: edible insect; entomophagy; cookie; biscuit; cracker; sustainability

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1. Introduction

There is 11% percent of starving people in the world, nearly two billion people are influenced by nutrient deficiencies, and the world population is ever-increasing which is predicted to reach 9.7 billion by 2050 [1]. Therefore, food security is becoming a major problem, and thus sufficient nutrition should be provided immediately, especially the countries which in poverty. In this regard, edible insects could be a promising source to meet the demand, particularly as an alternative resource of protein [2]. The main reasons behind using edible insects are having high nutritional value, especially in terms of high quality and amount of protein, lipid, vitamin, and mineral composition, together with the issues related to environment and sustainability, and also some economic factors. In this regard, edible insects also reduce water pollution, greenhouse gas emission, and pesticide usage. Moreover, they have a short reproduction cycle, high growth rate, high feed conversion ratio, and widespread distribution when compared with livestock [3]. Therefore, FAO has been evaluating the possibility and potential of utilizing edible insects for feed and food to meet food security, since 2010 [4]. However, the consumption of edible insects as food, in other words, entomophagy, emerged approximately 7000 years ago [5]. It is known that there are more than 2000 species of edible insects in the world [6], and the most consumed ones are ants, bees, crickets, flies. Most recently, it is the first time the consumption and marketing of an edible insect as a novel food, has been approved by the European Commission. The mentioned edible insect is the yellow mealworm' which refers to the larvae of the beetle *Tenebrio molitor* [7]. As a result, the market of edible insect-based food products is going to grow quickly, gain more place in the markets, and thus, is predicted to produce reach nearly 260,000 tonnes by 2030, according to the International Platform of Insects for Food and Feed [8].

2. Effects of Using Edible Insects on Nutritional Values and Technological Properties of Cookies, Biscuits, and Crackers

The bakery products are more promising food products to enrich with powder forms of edible insects that could develop not only nutritional value but also influence both technological and sensory properties of end-products [9]. However, there is limited study in the literature, regarding cookies, biscuits, and crackers enriched with edible insects, as summarized in Table 1. The commonly used edible insects are cricket [9–11], termite [11–15], grasshopper [16], locust [10,17], silkworm pupae [17], mealworm [18], and palm weevil larvae [19], which are generally replaced with raw material in concentrations between 5–25% for those bakery products, as seen in Table 1. Moreover, termites are the most used ones by researchers from among them. It has also been revealed that the crackers enriched with particularly winged termites are more preferred than crickets. The crackers also had the highest values of sensory features which are not significantly different from than control sample. This was attributed to whose high fat content, which influences flavor and texture, positively [11].

The protein and fat content were increased while carbohydrate and fiber content was decreased in cricket-enriched biscuits when compared to the control sample without the addition of edible insects [9]. A similar pattern, except fiber content, was observed in baby biscuits containing wood grasshopper flour [16], biscuits fortified with palm weevil larvae [19], and biscuits and cookies including termites [13,15]. The biscuits enriched with silkworm pupae were higher content of protein and fat, whereas a slightly lower content of carbohydrate, ash, and fiber than locust-enriched biscuits. Moreover, the pro-vitamin A and vitamin C composition are twice higher in both biscuits made with these edible insects, according to The United States Agency for International Development commodity specification for high-energy biscuits [17]. The mineral composition enhanced when using locust [17], termite [13,14], grasshopper [16] in biscuit formulations. In addition, saturated fats were dominated and caproic acid together with arachidic acid was the most abundant fatty acid in biscuits enriched with palm weevil larvae. However, lauric acid, myristic acid, and monounsaturated fatty acids were trace amounts in both biscuits supplemented with palm weevil larvae at both low and high concentrations [19]. The different drying methods altered the ratio of individual fatty acids [20]. On the other side, the protein digestibility was higher when compared to control cookies made with 100% wheat flour, also increased with augmenting concentrations of the winged termite in cookie formulations. In addition, the composition of essential amino acids, which is dominated by leucine and lysine, and were higher than the control sample and also generally meet the reference values of both children and adults according to the standard of FAO)/WHO, 2007 [12]. However, in vitro protein quality was decreased in baby biscuits including wood grasshoppers compared to control biscuits without edible insects for flour substitution. This was explained by the high fiber content of the grasshopper and also the Maillard reaction [16]. Moreover, the rapidly digested starch was decreased, whereas slowly digested starch content increased, and in vitro glycemic index did not change significantly in mealworm-added shortcake biscuit [18].

The skimmed milk powder was replaced at 15% concentration with two different edible insects as mulberry silkworm pupae and locust. Although no apparent defect was observed in some quality parameters in biscuits as thickness and spread ratio, the thickness was increased whereas spread ratio was decreased statistically, in edible insect-based biscuits compared to control sample containing skimmed milk. Moreover, while thickness values are higher in biscuits made with locusts, the spread ratio values are higher in biscuits containing silkworm pupae [17]. A similar tendency was observed in cookies enriched with termite at three different concentrations [12]. An adverse effect was observed in biscuits incorporated with termite (*Macrotermes subhyalinus*) [13,14]. On the other side, no significant differences were found in diameter when biscuits containing 5% percent of termites [13]. Adding the cricket powder into the flour mixture in the biscuit recipe increased values of a* and total titrable acidity, whereas a decline in L*, b* values. Moreover,

this tendency was increased when the addition of edible insect amounts was increased [9].

The drying parameters and drying methods of edible insects could affect not only nutritional quality, in terms of protein digestibility, fatty acid composition, and solubility of minerals [11], but also the volatile composition and odor characteristics, and thus sensory properties of end-products [20]. In this regard, winged termites were oven-dried at three different temperatures at 90, 120, and 150 °C for 10 min to enrich the cracker recipe. According to results, nutritional value, in terms of protein digestibility and solubility of iron and zinc decreased whereas energy value increased, although sensory properties did not significantly affect by drying temperature [11]. On the other side, two different drying methods as freeze-drying and microwave-drying were applied to locusts and silkworms to determine the impacts on volatile profiles and sensory attributes of cookies enriched with edible insects. The microwave dried insects caused additional emission of pyrrole and pyrazin, and showed up a roasted odor which is typical for the Maillard reaction. [20].

Table 1. The effects of edible insects on a number of technological and sensorial properties of some bakery products.

Bakery Product	Edible Insect	Usage Ratio	Results	References
Biscuit	Mulberry silkworm pupae (*Bombyx mori*), Locust	15% [a]	Weight↓, Width↑: silkworm; ↔: locust, Thickness↑, Spread ratio↓, Sensory properties↔ (except aroma)	[17]
Biscuit	Termite (*Macrotermes subhyalinus*)	5, 10, 15, 20, and 25% [b]	Weight↓, Diameter↑ (except 5% inclusion), Thickness↓, Spread ratio↑, Specific volume↔, Sensory properties↔	[13]
Biscuit	Termite (*Macrotermes nigeriensis*)	5, 10, 15, and 20% [b]	Weight ↑ , Diameter ↑ (except 5% inclusion), Spread ratio ↑ Breaking strength ↓ , Sensory properties: taste↓, aroma↔, texture↔, overall acceptability↓ (except 5% inclusion)	[15]
ShortcakeBiscuit	Mealworm (*Tenebrio molitor*)	1:9, 1:14, 1:19 [c]	Diameter↔, Thickness↔ (except 1:9 inclusion), Spread ratio↔ (except 1:9 inclusion), L*↓, a*↑, b*↓, Browning index↑	[18]
Biscuit	Cricket (*Acheta domesticus*)	5, 10, and 15% [b]	Color: L*↓, a*↑, b*↓, Texture: hardness↔, Sensory properties: odor↔, flavor↓ (except 5% inclusion), color↓ (except 5% inclusion), texture↔, overall liking↓	[9]
Biscuit	Termite (*Macrotermes subhyalinus*)	5, 10, 15, 20, and 25% [b]	Weight↓, Diameter↑, Thickness↓, Spread ratio↑, Specific volume↓, Sensory properties: taste↔ (except 25% inclusion), aroma↔, color↓, texture↔ (except 20 and 25% inclusion), appearance↔, overall acceptability↔	[14]
Baby biscuit	Grasshopper (*Melanoplus cinereus*)	5, 7, and 10% [a, b]	Sensory properties: taste↑, aroma↑, color↑, texture↑	[16]
Cookie	Termite (*Macrotermes belliscosus*)	5, 10, and 15% [b]	Weight↓, Diameter↓, Thickness↑ (except 5% inclusion), Spread factor↓, Color: L*↓, a*↑, b*↑, Texture: hardness↓, fracturability↑	[12]
Cracker	Cricket, Termites (soldier termite, winged termite)	8% [b]	Sensory properties: taste↓, flavor↓, aroma↓, color↓, appearance↓, overall acceptability↓	[11]

↓ indicates increment is statistically different; ↑ indicates decreasement is statistically different; ↔ indicates increment or decreasement is not statistically different. [a]: the concentration in the whole recipe; [b]: the ratio of raw material replacement; [c]: the ratio between edible insect to raw material (edible insect: flour).

3. Effects of Using Edible Insects on Sensorial Properties of Cookies, Biscuits, Crackers and Their Consumer Acceptance

The most effective factor for the decision of eating or avoiding insect-containing foods is cultural background [21]. The other drawbacks of edible insect-based food products are based on concerns of health and food safety, but also some organoleptic features as flavor, aroma, color, and texture [22]. Therefore, there are some strategies generally based on farming (breeding and diet) and processing methods of edible insects to enhance the sensorial appeal of edible insects which incorporate into food formulation. Moreover, adding edible insect powder together with flour where they are not visible, to most consumed and familiar foods like bakery products, has a great potential to overcome these barriers for increasing consumer acceptability. On the other side, the rearing and also

processing methods and parameters of edible insects like defatting, drying, heat treatments, and protein extraction have an impact upon sensory attributes of end-products [21]. Microwave-dried and freeze-dried locusts were more preferred by panelists instead of raw insects and oven-dried insects. However, there were no significant differences between the control sample and the cookies enriched with locusts that were exposed to different drying methods. Moreover, the caramelized and bready notes were dominated, although odor intensity varied among different drying methods. In addition, the raw ground form of silkworms had high overall liking scores than raw-locusts. Freeze-dried samples had similar overall liking scores with control cookies without insects. However, the cookies including microwave-dried locusts had the strongest aroma intensity with dominated fishy odor, and thus, were the least liked ones [20]. On the other hand, none of the sensorial attributes (taste, color, appearance, crispiness, and overall acceptability) except aroma were affected by the replacement of skimmed milk powder by the edible insect as locust and silkworm pupae in the biscuit recipe [17]. Similar results were obtained, for texture instead of crispiness, as well in biscuits including termite [13]. In another study, odor and texture properties were not affected by the inclusion of cricket in the biscuit recipe. However, the values of color, flavor, and overall liking were lower than oat flour-based control biscuits, which is more obvious in biscuits containing more than 5% cricket. Therefore, the biscuits with a high amount of edible insects were rejected by panelists, although the biscuits enriched with 10% and 15% cricket could be labeled as protein sources according to European Union's Regulation No. 1924/2006. In addition, while cheesy and fatty flavors had a positive impact on overall liking, burnt flavor and color had a significantly negative effect on overall liking, according to results of check-all-that-apply (CATA) questions [9].

To promote intake of protein and iron to decrease the incidence of malnutrition and anemia in pregnant women, biscuits were enriched with palm weevil larvae. The women were willing to buy these biscuits in markets, and these biscuits were acceptable in terms of sweetness, aroma, color, and texture, according to the results of the sensory evaluation [19]. In a study, the acceptability and sensory attributes (the liking and intensity of hardness, crunchiness, bitterness, flavor-strength, etc.) of chocolate chip cookies in which wheat flour was replaced by cricket flour at two different concentrations (15 and 30%), were evaluated, by 200 consumers from each of three different countries, like USA, Spain, and Mexico, using a nine-point hedonic scale. The cookies enriched with insects in the amount of 30%, was acceptable as a control sample for Mexican consumers because of being more familiar with insect-based food products, in those countries [23]. To determine the most consumed and/or preferred edible insect between four different edible insects (termites, crickets, grasshoppers, and palm weevil), the survey-demonstrating pictorial representation for ranking were addressed 79 consumers from the rural community in Nigeria. According to the results, termite was the most liked one, because of being cheap and available locally, and needs less time for cooking together with better taste. On the other side, cricket was the least preferred insect among them due to being expensive and taking more time for cooking. Later, termites were used with sorghum flour at the ratio 1:3 as a composite flour to substitute wheat flour at three different concentrations as 20, 40, and 60% for biscuit production. To investigate the acceptability of termite as an ingredient of biscuits, sensorial attributes like taste, aroma, color, texture, and overall acceptability, were assessed using a five-point facial hedonic scale, by 84 consumers who have no allergies and eat up and/or willing to try biscuit and insect. Although biscuits supplemented with insects had an uneven surface, the biscuits enriched with 5% termite, had better results in all attributes than the control sample, made with 100% wheat flour. Moreover, the texture parameters were not affected by the increase in insect concentrations, whereas intense brown color was monitored which led to the highest amount of added insect biscuits was the least acceptable by consumers [24]. In another study, a four-week-long parallel randomized study was conducted to assess the acceptability of biscuits containing edible insects, to suitability for school feeding programs in Kenya. This is because Kenyan children are under risk of undernourishment and milk powder is expensive and

does not produce locally. Therefore, the house cricket at the ratio of 10% was used in the biscuit formulation instead of milk powder. To determine acceptability, the weight of eaten biscuits were collected daily and the sensorial attributes (looks, color smell, taste, texture, and overall) were evaluated once a week with a five-point facial hedonic scale by 54 Kenyan children at the age between 5–10. The score of most sensorial properties, except color and taste, were lower than the control sample but above the average score which was defined as 2.5, although the color of biscuits containing insects was darker and their size is relatively bigger than milk biscuits. Moreover, the consumption of biscuits was determined as about 97% and 94% for insect-based and milk powder-based biscuits, respectively [25].

4. Conclusions

The edible insects gained a place in the baked goods, like biscuits, cookies, and crackers, followed by bread. The edible insects are mainly using in the recipe of those baked goods, for generally replacement of different kinds of flours, at the range of generally 5% to 25%. Among the edible insects, termites are the most used and preferred ones. Although the results of some sensory studies are promising, which indicates no significant differences with control samples are found, there are still limitations for consumer acceptability, although edible insects have high nutritional value and higher digestibility than plant-based proteins. The limitations are much more related to sensorial attributes together with neophobia or concerns related to health. However, using edible insects could still be a good alternative and valuable resource to enrich bakery products by increasing the nutritional value and meet the protein shortage. Therefore, further studies should mainly focus on making edible insect-enriched food products more appealing for the consumers by modifying food formulation or masking some off-flavors, and also determine the optimum conditions about pre- (rearing) and post-processings of edible insects (drying, defatting, etc.).

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