The use of yellow mealworms in common food products

Kosta Nikolić and Jelena Tepavčević*

University of Novi Sad, Faculty of Science, Department of Geography, Tourism and Hotel Management; nikolickosta1@gmail.com; jelenat91@gmail.com

*Correspondence: jelenat91@gmail.com

Abstract:

In many cultures worldwide, eating insects is a traditional practice known as entomophagy. In general, it has been discovered that insects are very nutrient-dense and good sources of protein, fat, minerals, vitamins, and energy. Given their high nutritional value and minimal environmental impact, edible insects are increasingly being recognized as potential food sources for humans. The green light for using edible insects was given for the following species - Tenebrio molitor, Acheta domesticus, Alphitobius diaperinus, and Locusta migratoria. Out of them, Tenebrio molitor is the most widely researched and used species. Considering many potential uses of Tenebrio molitor in commercial food, this paper will summarize the potential of their use in food such as bread, meat products, and sauces. This paper will also provide an overview of the nutritional value of dried Tenebrio molitor.

Keywords: Edible insects; Yellow mealworms; Food; Tenebrio molitor

1. Introduction

Edible insects are increasingly being recognized as a potential source of food for humans due to their high nutritional value and low environmental impact [1]. In many parts of the world, insects have been consumed traditionally for centuries. However, their use as a food source has been largely ignored in Western societies, where insects are often seen as pests rather than viable food options. In recent years, there has been growing interest in using edible insects as a sustainable and nutritious alternative to traditional meat sources. Neophobia is an important factor when it comes to rejection. Only a slight increase in neophobia drastically increases rejection [2,3]. Research has shown that consumers are more open towards products that do not have visible insects or if they are incorporated into familiar products [4–8].

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2. Nutritional value of edible insects

Edible insects are a rich source of protein, vitamins, and minerals. Many species contain all nine essential amino acids, making them a complete protein source [9]. In addition to protein, insects are rich in iron, zinc, and calcium [10–14]. The nutritional content of insects can vary widely depending on the species and the stage of development. Still, in general, they offer a high-quality source of nutrients for human consumption. EFSA gave the green light for four species of edible insects - Tenebrio molitor, Acheta domesticus, Alphitobius diaperinus, and Locusta migratoria. Table 1 shows the macronutrients of dried Tenebrio molitor larvae and fiber, ash moisture, and energy value per 100 grams of the food. EFSA required that the producer brings different samples (at least 5 for every segment) of TM produced using defined methods and procedures. Batches represent those different samples, which was done to ensure reliance on these results.

Table 1. Analysis of components of dried Tenebrio molitor (TM) [11]

Parameter (unit)	Batch number (dried mealworms)					Analytical method
	#6	#7	#8	#9	#10	
Crude protein (g/100 g of TM)	54,5	54,3	56,6	56,6	55,9	Kjedahl (N × 6,25)
Fat (g/100 g of TM)	28,7	28,4	28,4	28,6	28,9	Gravimetric method
Digestible carbohydrates (g/100 g of TM)	6,06	5,84	6,53	6,37	6,24	Titrimetry-Luff school
Dietary fiber (g/100 g of TM)	4,4	4,6	5,1	5,0	4,7	Enzymatic-gravimetry-AOAC 2009.01
Sugars (g/100 g of TM)	<0,1	<0,1	<0,1	<0,1	<0,1	hpaec-pad
Ash (g/100 g of TM)	3,68	3,77	4,02	4,09	3,76	Gravimetric method
Moisture (g/100 g of TM)	3,13	3,16	0,66	0,58	1,77	Gravimetric method
Energy value (kJ/100g of TM)	2100	2100	2200	2200	2200	Regulation EU (1169/2011)

Table 2. shows the content of micronutrients in dried TM. Mealworms are a good source of various vitamins, including B vitamins such as thiamin (B1), riboflavin (B2), niacin (B3), and vitamin cyanocobalamin (B12). TM are rich in phosphorus, magnesium, potassium, and zinc minerals.

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Table 2. Micronutrients in dried Tenebrio molitor (TM) [11]

Parameter (unit)	**Analytical method**	**6**	**7**	**8**	**9**	**10**
Minerals						
Calcium (mg/100g)	ICP-MS	75	78	80	80	78
Copper (mg/100g)		1,5	1,4	1,5	1,6	1,5
Iron (mg/100g)		5,3	5,5	5,2	5,5	5,6
Magnesium (mg/100g)		200	190	190	200	190
Manganese (mg/100g)		0,69	0,69	0,64	0,65	0,67
Phosphorus (mg/100g)		740	800	840	800	830
Potassium (mg/100g)		1000	1000	1100	1100	1100
Sodium (mg/100g)		190	190	210	220	200
Zinc (mg/100g)		14	14	15	16	14
Iodine (µg/100g)		0,051	0,051	0,049	0,047	0,047
Selenium (µg/100g)		0,055	0,029	0,036	0,040	0,036
Boron (mg/100g)	ICP-OES	0,39	0,35	0,30	0,35	0,40
Molibdenum (mg/100g)		<0,2	<0,2	<0,2	<0,2	<0,2
Vitamins						
Retinol (µg/100g)	EN 12823-1 2014	<21	<21	<21	<21	<21
Thiamin (mg/100g)	EN 14122:2003, mod.	0,30	0,31	0,33	0,33	0,33
Riboflavin (mg/100g)	EN 14152:2003, mod.	0,75	0,79	0,76	0,72	0,7
Niacin (mg/100g)	EN 15652:2009	1,12	1,09	1,17	1,15	1,13
Pantothenic acid (mg/100g)	AOAC 2012.16	5,31	5,44	6,34	6,24	5,75
Pyrodoxine hydrochloride (mg/100g)	EN 14164	0,180	0,173	0,181	0,307	0,194
Biotin (µg/100g)	LST AB 266.1,1995	172	167	157	192	177
Folic acid (µg/100g)	AOAC 2013.13	<5	<5	<5	<5	<5
Cyanocobalamin (µg/100g)	AOAC 2008, vol91 no4	0,319	0,316	0,317	0,338	0,329
Cholecalciferol (mg/100g)	EN 12821:2009	<0,25	<0,25	<0,25	0,524	0,499
Alpha-tocopherol (mg/100g)	EN 12822:2014	1.05	1,10	1,33	1,76	1,13

3. Overview of scientific experiments that tried adding T. molitor to common food products

Joo-Hyoung Cho et al. [15] made different fermented sauces using a method for making soy sauce. *Tenebrio molitor* larvae were used. Meju, koji and roasted rice flour and 23% brine were used to make the sauce. Insect meju was made by using *A. oryzae and B. licheniformis* to ferment raw or defatted insect larvae while insect koji was made with defatted insects with *A. oryzae*. Six different sauce samples with two different ratios of ingredients (meju:koji: roasted rice flour = 6:2:2 and 8:1:1) were prepared with raw T. molitor larvae (raw insect sauce), defatted larvae (defatted insect sauce), and soy (soy sauce) after 20 days of fermentation at 25°C. Results showed that there was no difference in lightness of samples. Raw insect sauce had higher brightness. Browning increased as time passed, but in the case of defatted insect sauce, it sharply decreased on day 20. Amino acids and amino acid derivatives increased 1.5–2 times during fermentation. Also, a taste test was conducted. Sauces made from insects didn't have a statistically significant lower evaluation, so the authors concluded that sauces made from insects could be commercialized.

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Some researchers have explored the possibility of substitution of lean pork meat with T. molitor larvae [16,17]. It was possible to replace lead meat with insects but only to a certain extent [16,17]. The moisture content, fat content, lightness, sarcoplasmic protein solubility, hardness, gumminess, chewiness, and apparent viscosity of frankfurters with yellow mealworm were lower than those of the control. In comparison, the protein and ash content, pH, and yellowness of frankfurters with yellow mealworm were higher than those of the control. Also, frankfurters that contained insects were less juicy and had lower taste and color scores. Consumer acceptance wasn't significantly different between the control group and samples with 5% and 10% of T. molitor larvae. Authors concluded that it's possible to substitute up to 10% of lean pork meat with insects without consumer complaining.

Bread is the base of diets of many cultures. That's why some scientists explored adding ground mealworms to bread dough. Roncolini et al. [18] showed that adding mealworm powder did not negatively affect the technological features of either dough or bread. All the tested dough showed the same leavening ability, while bread containing 5% MP showed the highest specific volume and the lowest firmness. Protein content increased with the increase of percent of mealworm powder in the bread. Bread fortified with 10% MP also exhibited a significant increase in the content of free amino acids. The nutritional quality of lipids was the same in both the control group and experimental bread. Khuenpet et al. [19] showed that adding mealworm powder will increase the protein content and hardness of the final product. Also, bread that had more insects was darker in color. Bread with 5% of larvae had the closest quality to the control bread. Cozmuta et al. [20] had a different approach. They were testing whether bread containing T. molitor larvae or Acheta domesticus has better bioaccessibility of minerals. Results showed higher bioaccessibility of Na, K, Ca, Mg, P, Fe, Zn, Mn, and Li from insect bread than white bread. Only copper was more bioaccessible in white bread without insects. Authors concluded that insects could be used to increase protein and mineral content in bread as a way to fight deficiency.

4. Conclusions

Tenebrio molitor, an edible insect, is simple to raise and can offer protein with a high nutritional value [21,22]. As the examples above showed, Tenebrio Molitor larvare (and other insect species) could be used in everyday food products to increase their nutritional value while preserving their sensor acceptability. This could also represent baby steps towards acceptance of edible insects in Western societies.

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