EDIBLE INSECTS AND MODERN APPROACHES TO THEIR USE-SCIENTIFIC ANALYSIS

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ABSTRACT

This article highlights the edible insects and their potential uses in practice. Furthermore, a scientific analysis of the types of edible insects widely used by the world community, their nutritional value and the specifics of their production, the existing problems and their solutions are provided. The problems of feed additives in the livestock, poultry and fisheries of the Republic of Uzbekistan, as well as scientific and practical approaches to the role of edible insects in overcoming these problems are also discussed. The information presented in this article serves as a scientific source for the production and implementation of products based on edible insects.

Key words: Edible insects, nutritive insect, food, feed, protein, fat, breeding, *Tenebrio molitor*, produce

Animal husbandry is known to be one of the most productive sectors in the world, resulting 35% of global production. For the development of this sector, 75% of agricultural production and 8% of the world's drinking water are spent on the development of this industry (Foley Jonathan et al., 2011). In addition, the livestock sector emits 14.5% of all anthropogenic greenhouse gases, which is about 7.1 gigatons of CO_2-equivalent per year (Gerber et al., 2013). Livestock production also requires very high water consumption (Mekonnen and Hoekstra, 2012.). As a result, the production of livestock products requires a very large amount of reserve resources, taking into account the production of fodder. This justifies that the cultivation of food products that are easy to produce, inexpensive and rich in all the necessary ingredients is one of the most pressing problems. By industrially reproducing insects with a nutrient-rich chemical composition, it is possible to create an unlimited potential supply of feed and feed additives manufacturing industry for the livestock sector. The fact that the production of insects is very convenient on the basis of low-cost secondary organic products or on the basis of biological waste products shows that the importance of these biological objects is very high.

Researchers have found that it is possible to prepare 2 kg of forage from one kilogram of insect biomass (Collavo et al., 2005). Insects can also consume a variety of recycled waste products, converting them into high-nutritional feeds. By reproducing insects in very large quantities on an industrial basis, it has been proven that they can be used as an alternative to the production of food products with high nutritional value (Veldkamp et al., 2012). According to the FAO (2011), by 2050, the demand for meat products will increase by 58% and the demand for dairy products by 70% compared to 2010. Livestock production also requires a large amount of water (Mkandawire and Dudel, 2005). As a result, the cultivation of livestock products requires a very large amount of reserve resources, taking into account the production of fodder. This shows that the cultivation of food products that are easy to produce, inexpensive and rich in all the necessary ingredients is one of the most pressing problems.

MATERIALS AND METHODS

In preparing this scientific analysis, four directions were taken as the main source. Species of edible insects widely used in the world scientific community; nutritional units and applications of edible insects; problems arising from the introduction of the practice of edible insects; and some problems in the use of edible insects in the example of the Republic of Uzbekistan. In order to study these issues in detail, scientific articles, which were published in recent years under the term "edible insects" from peer-reviewed scientific journals included in the Google Scholar database, were analyzed. Admittedly, this database does not contain any information on the use and study of edible insects in Uzbekistan, except for our scientific sources. From more than 30,000 identified scientific sources, 13 articles with the largest scientific analyzes were selected, on the basis of which a comparative analysis of the existing problems in the Republic of Uzbekistan and scientific conclusions were made.

RESULTS AND DISCUSSION

In the world fisheries industry, soy flour and fish flour are recognized as the main sources of nutritious food. Wheat flour and corn flour are also widely used as basic food in fisheries. Soy flour contains 44-54% protein and 2-3% fat (Adámková et al., 2016), while fish flour contains around 48-75% protein and 9-11% fat (Vrabec et al., 2015). One of the global problems is the sharp change in natural climatic conditions, drought due to abiotic and biotic factors, increasing salinity and soil degradation have resulted in a reduction in the area under agricultural crops, as well as major problems in the cultivation of agricultural products under the influence of various pests and diseases. By industrially reproducing insects with a nutrient-rich chemical composition, it is possible to create an unlimited potential stockpile for the feed industry and feed additives manufacturing industry for the livestock sector (van Huis et al., 2013). The fact that the production of insects is very convenient in low-cost secondary organic products or on the basis of biological waste products shows that the importance of these biological objects is very high (Collavo et al., 2005).

Insects can also consume a variety of recycled waste products, converting them into high-nutritional feeds. It has been shown that by reproducing insects in very large quantities on an industrial basis, they can be used as an alternative to the production of food products with high nutritional value (Veldkamp et al., 2012). In particular, it was determined that different insects contain protein and fat in their body, such as, *Tenebrio molitor* (larva) - protein 44-64%, fat - 17-43% (Finke, 2002), (Bukkens, 1997), *Alphitobius diaperinus (larva)* - protein 58 -65%, fat 22- 29% (Diener et al., 2009), *Acheta domestica (adult)* - protein 58-74%, fat 14-23% (Oonincx et al., 2011), *Gryllodes sigillatus (adult)* - protein 70%, fat-18% (Ravzanaadii et al., 2012), *Locusta migratoria (adult)* - protein 56-65%, fat 13-30% (Bednarova et al., 2013), *Hermetia illucens (larva)* - protein 32-52%, fat 12-42% (Rumpold and Schluter, 2013). Therefore, edible insects can be mentioned as an alternative source in providing the livestock, poultry and fishing industry with a continuous nutrient base.

By 2050, the number of people in the world is expected to increase over 9 billion. (Grafton et al., 2015; Park and Yun, 2018). With the current production capacity and agro-ecological situation and the existing agricultural opportunities, it is not possible to provide so many people with sufficient and nutritious food (Dobermann et al., 2017). Also, due to drastic changes in climatic conditions, the problems in food production are increasing day by day. This requires the search for alternative sources of food substitutes for existing traditional food products and their in-depth scientific and practical research. As one of such alternative sources, edible insects can serve as a source. As a result of ongoing research, model technologies for the production of high nutritional value products for dietary foods based on edible insects are being developed (Gao et al., 2018).

Due to the rapid development of livestock, poultry and fisheries, which are among the priorities in food production, the problem of providing these industries with uninterrupted and nutritious food products is growing rapidly (Khujamshukurov N.A. 2011). In recent years, the production of compound feed additives based on food insects has become one of the most common methods in agriculture. According to Van Huis (2013), a mixed feed based on locusts grown under controlled conditions (Acheta domesticus) was found to be twice as effective in chickens, four times in pigs, and more than 12 times in cattle. The technological process of foraging insects is characterized by very little damage to the environment compared to other types of production, including very low emissions of NH_3 and greenhouse gases compared to the cattle breeding process (Oonincx and Van der Poel, 2011). It also requires very little land area compared to the land area required for raising chickens, pigs or cattle for the production process to produce consumable protein based on 1 kg of flour beetle and therefore emits very little greenhouse gases into the environment (Oonincx and Dierenfeld, 2012).

In addition to its low impact on the environment, it is characterized by a very high level of productivity and the ability to organize the production process independently of the seasons. In particular, cattle or pigs cannot be fed with any type of plant mass, which can be used on very large-scale plant species to grow insects. This also leads to a sharp reduction in the problem of forage in their cultivation (Durst and Shono, 2010) and further reduces the cost of production (Mirzaeva et al., 2020). In world practice, it has been noted that *Hermetia illucens, Tenebrio molitor, Acheta domesticus, Alphitobius dioperinus, Zophobas morio* have a wide range of applications as insecticides and feed additives.

One of the main challenges is to create a low-cost and cost-effective food base in the process of growing animals to provide them with complete nutritional value, animal meat, poultry and eggs, fish and fish products. In particular, the issue of providing the fishing and poultry industries in the Republic of Uzbekistan with low-cost and energy-efficient food products remains very important. This can be seen in the fact that for the second half of 2017 and the first half of 2018 alone, the state directed 630 thousand tons of wheat to the production of fodder in the production of livestock products. However, by directing this amount of wheat to the production of food for humans, there is a possibility to replace it on the basis of non-traditional food insect biomass (Khujamshukurov and Nurmukhamedova, 2016; Mirzaeva et al., 2020). This puts the task of providing scientists with ecologically safe food products with full nutritional value to the world's scientists. Many methods and technologies have been put into practice by scientists around the world to solve this problem. One of the most convenient and inexpensive alternatives to these is to grow these edible insects and use them as food and feed products.

Table 1 shows the protein and amino acid compositions that determine the nutritional values of some of the edible insects reflected in scientific sources. One of the most promising areas of modern production is the development of food products based on edible insects, which are easy to store in terms of high protein and low fat content and easy digestion (Tables 1-3). In Uzbekistan, the production and use of food products and additives based on food insects has not yet been implemented. However, economic growth in the world market based on food insects in 2019 will reach $ 112 million and is projected to increase by another 47% in 2019-2026 (Industry Forecasts, 2020). At the end of 2019, the economic indicator in the total market of edible insects was 24.18 million dollars, with the share of European countries being 10.34 million dollars (Kunal Ahuja and Kritika Mamtani, 2020). This indicates that there is competition for the further development of stable economic indicators in the edible insect market. Therefore, one of the most promising areas in Uzbekistan is the production of edible insects under controlled conditions, the introduction of the use of products based on them in the livestock, poultry and fisheries sectors. In addition, the chances of breeding insects under controlled conditions and setting up a small business without attracting large sums of money are very high. It also ensures that farms organize their own production, obtain high-protein products and lower their cost.

Although, in this research, the theory of "insect→ to insect" was used to optimize the growth rate, biomass,

Table 1. Protein and fat storage of some edible insect species (relative to dry matter, %)

Types of insects	Scientific name of insects	Protein	Fat	Scientific sources
Larvae	*Allomyrina dichotoma*	54,18	20,24	Ghosh et al. (2017)
	Anaphe infracta	20,00	15,20	Banjo et al. (2006)
	Anaphe recticulata	23,00	10,20	Banjo et al. (2006)
	Anaphe venata	25,70	23,21	Banjo et al. (2006)
	Gonimbrasia belina	56,95	10,00	Siulapwa et al. (2014)
	Gynanisa maja	55,92	12,10	Siulapwa et al. (2014)
	Protaetia brevitarsis	44,23	15,36	Ghosh et al. (2017)
	Rhynchophorus phoenicis	22,06	66,61	Ekpo and Onigbinde (2005)
	Tenebrio molitor	46,44	32,70	Ravzanaadii et al. (2012)
Bugs	*Heteroligus meles*	38,10	32,01	Jonathan (2012)
	Oryctes boas	26,00	1,50	Banjo et al. (2006)
	Rhynchophorus phoenicis	50,01	21,12	Jonathan (2012)
	Rhynchophorus phoenicis	28,42	31,40	Banjo et al. (2006)
Grashopper	*Brachytrypes* spp.	6,25	2,34	Banjo et al. (2006)
	Gryllus bimaculatus	58,32	11,88	Ghosh et al. (2017)
	Teleogryllus emma	55,65	25,14	Ghosh et al. (2017)
Termites	Macrotermes bellicosus	20,10	28,20	Banjo et al. (2006)
	Macrotermes falciger	43,26	43,00	Siulapwa et al. (2014)
	Macrotermes notalensis	22,10	22,50	Banjo et al. (2006)
Spider	*Apis mellifera*	21,00	12,30	Banjo et al. (2006)

Table 2. Energy value of insect species by areas

Area	Local name	Scientific name	Energy value (relative to dry matter kcal/ 100 г)
Australia	Australian plague locust, raw	*Chortoicetes terminifera*	499
Australia	Green (weaver) ant, raw	*Oecophylla smaragdina*	1 272
Canada, Quebec	Red-legged grasshopper, whole, raw	*Melanoplus femurrubrum*	160
USA, Illinois	Yellow mealworm, larva, raw	*Tenebrio molitor*	206
USA, Illinois	Yellow mealworm, adult, raw	*Tenebrio molitor*	138
Ivoru Coast	Termite, adult, dewinged, dried, flour	*Macrotermes subhyalinus*	535
Mexico, Veracruz	Leaf-cutter ant, adult, raw	*Atta mexicana*	404
Mexico, Xidalgo	Honey ant, adult, raw	*Myrmecocystus melliger*	116
Thailand	Field cricket, raw	*Gryllus bimaculatus*	120
Thailand	Giant water bug, raw	*Lethocerus indicus*	165
Thailand	Rice grasshopper, raw	*Oxya japonica*	149
Thailand	Grasshopper, raw	*Cyrtacanthacris tatarica*	89
Thailand	Domesticated silkworm, pupa, raw	*Bombyx mori*	94
The Netherlands	Migratory locust, adult, raw	*Locusta migratoria*	179

FAO, 2013.

Table 3. Protein storage depending on the developmental of the insect species (Xiaoming et al., 2010)

Insect species	Developmental stage	Protein storage, %
Coleoptera	bug and larva	23 – 66
Lepidoptera	pupa and larva	14 – 68
Hemiptera	bug and larva	42 – 74
Homoptera	bug, larva, egg	45 – 57
Hymenoptera	bug, larva, egg	13 – 77
Odonata	Adults and naiad	46 – 65
Orthoptera	Adults and nymph	23 – 65

protein and fat storage of Tenebrio molitor larvae, and to increase the fat storage of larvae, in the future, the use of forage and feed additives based on other food insect species as a source of protein, fat, vitamins or minerals in the cultivation of these larvae under controlled conditions should be widely introduced in practice.

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AUTHOR CONTRIBUTION STATEMENT

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CONFLICT OF INTEREST

The authors have no conflict of interests

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