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The effect of the addition of cricket flour as an added value on the quality of sausages

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CONTENT

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INTRODUCTION

People have been consuming insects tens of thousands of years ago and still do an important place in menus in many parts of the world. It is estimated that insects currently consumed by approximately 2 billion people, while there are more than 2000 edible ones insect species, especially in tropical countries. The very idea of eating insects is nothing new.

Interest increased rapidly after the FAO (Food and Agriculture Organization) issued in 2013 publication entitled "Edible Insects: Future prospects for food and feed security". This one report includes basic information about entomophagy, benefits of eating insects, nutritional the composition of individual types of insects, but also possible risks associated with the consumption of insects. After the release of this report, not only a wave of media interest, but also academic interest was launched research and, last but not least, commercial interest. By 2018, it was worldwide registered about 267 companies that process insects in various forms.

However, the adoption of this alternative source of protein in Slovakia lags behind, mainly due to people's resistance and lack of information. Well, considering the growing world population, it is only a matter of time before we start this issue deal with in Slovakia as well. In the neighboring Czech Republic, they are already working on this issue several years and currently it is not a problem to buy food in selected chains insect base. The world population is growing and is expected to reach 9 billion by 2050 people, which means that it will be necessary to increase food production by almost two times.

Insects are considered a sustainable alternative, but in Western countries, this is the only option he views the possibility rather with reluctance. There can be several reasons: aesthetic point of view, insufficient media coverage and knowledge about entomophagy in Slovakia, as well as food neophobia (fear of a new food caused by its unknown properties). However, the solution to this problem is simple. Many researches have proven that acceptability of insects in the general public is higher if the insects are processed into an "invisible" form that is for example in the form of flour and its subsequent addition to various types of products. It is too it is possible to obtain individual valuable components from insects (such as fats, proteins, vitamins) by simple extraction. There are many possibilities, but this issue requires even more depth research.

In our work, however, we do not try to promote the idea that he should insects completely replace basic food. We just want to point out its potential as an additional ingredient to food or in the form of food supplements.

 DOI: https://doi.org/10.15414/2022.9788055225661

1 LITERATURE REVIEW

It is estimated that the demand for meat should increase by 76%. Considering the negative, the impact of the animal industry on the environment - deforestation, soil erosion, emissions greenhouse gases and water pollution - increasing production is not sustainable a sustainable solution to the future demand for proteins. For the mentioned reason, it is necessary look for alternative sources, which can also be edible insects (Marberg et al., 2017).

According to Van Huis (2015), animal production accounts for more than 14% of all of greenhouse gas emissions and 59-71% of global ammonia emissions.

1.1 History and present of entomophagy

Insects, invertebrates, have a huge biodiversity and their biomass represents 95% animal kingdom. They can be consumed in different stages of their development, as eggs, larvae, pupae, and adults, which are consumed from prehistoric times to the present, but it is in the form of larva or pupa that most of the registered species is consumed. When consumed indirectly, the intake is in the form of products made and/or excreted by these insects, such as: honey, wax, pollen, oils, dyes, medicines, teas, infusions, and flours, added or not to other ingredients: eggs, larvae, pupae or as adults (Stamer, 2015; Ohara et al., 2018).

Insects have been on this planet for about 350 million years (humans about 1 million) and are the existence of not only plants but also animal species depends on it. For example, if from the world the bees, which ensure the pollination of plants, disappeared, humanity would probably survive only another 4 years. Without termites, entire ecosystems of tropical rainforests would collapse, which would mean a change in the frequency and intensity of rains and the oxygen cycle on Earth (Borkovcová et al., 2009).

Dossey et al. (2016) state that the consumption of insects is historically and geographically an old, widespread phenomenon and varies considerably according to local customs, sociocultural significance and region.

The rich history of insect consumption is also confirmed by analyzes of fossils from caves in the USA and Mexico. For example, coprolites from caves in Mexico included ants, larvae, bugs, mites. Another proof is the paintings in the caves of Altamira in the north Spain (9000 – 3000 BC) (Kourimská et al., 2016).

 DOI: https://doi.org/10.15414/2022.9788055225661

According to Borkovcová et al. (2009) reports on entomophagy in antiquity are given in the Bible with a reference to John the Baptist, who supposedly lived on locusts and honey. The oldest written references to the consumption of insects come from Herodotus. Roman poet Aristophanes, on the other hand, describes vendors who sold "four-winged chickens" - grasshoppers. In the 16th century, there were reports of the consumption of insects by the Italian entomologist Ulis Aldrovandi. In Utah in 1855, settlers began to consume locusts, which they destroyed the crop.

Entomophagy – a method of obtaining nutrients important for humans at a minimum investment and burdening the environment has been gaining awareness recently even such conservative countries as the states of Europe. Insects can be legally consumed in Great Britain, China, South Africa, France, the Netherlands, Belgium and since 2017 also in Switzerland (Mangová et al., 2017).

Currently, it is estimated that entomophagy is practiced in at least 113 countries with over 2000 documented edible insect species. In Western culture, however, it is compared to the rest of the world, the consumption of insects has so far been considered eccentric, even though in recent years, entomophagy and its positive aspects have been increasingly discussed (Dobermann et al., 2017).

Suchý et al. (2017) consider the following to be the main advantages of insects:

- rapid sexual maturation and inclusion in the reproductive process,
- fast reproduction,
- rapid growth, especially in development stages (high biomass production),
- high feed conversion compared to farm animals.

For example, the feed conversion of the domestic cricket (*Acheta domesticus*) is 2x higher than in chickens, 4x higher than in pigs and more than 12x higher than in cattle. Compared to mammals and birds, insects may represent a smaller risk of transmission zootonic infections on humans, farm animals and wild animals (Van Huis et al., 2013).

Time also plays an important role. It is necessary to raise a cow intended for slaughter at least 1.5 years, while insects are suitable for processing in 2 months. Insect farms it is even possible to establish in the middle of cities without producing any odor (Pavelková et al., 2018).

Another positive aspect of entomophagy is the help in reducing the number of people used pesticides. Controlled collection of insects considered pests of agricultural crops, can contribute to less consumption of insecticides (Cerritos, 2008).

 DOI: https://doi.org/10.15414/2022.9788055225661

Van Huis et al. (2013) also mention the environmental benefits of insect farming. For example, crickets need only 3 kg of feed to gain 1 kg of body weight. Cattle need up to 40 kg of feed for the same increase (Fig. 1). At the same they produce less greenhouse gases and ammonia compared to cattle and pigs. And they also require significantly less land and water compared to cattle.

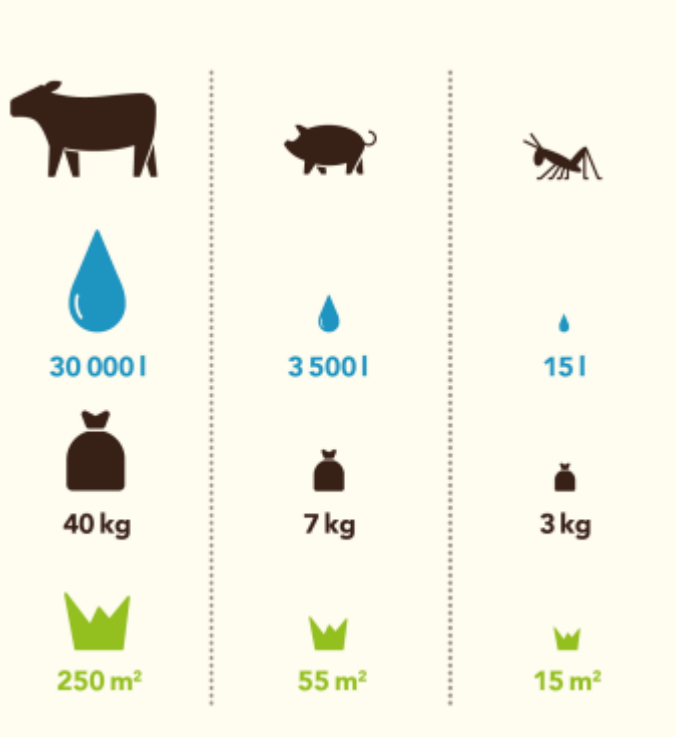

Figure 1: Requirements for the production of 1 kg of gain (URL 1)

It is known that some types of insects, such as adult locusts (*Zonocerus variegatus*) or larvae (*Cirina forda*) have comparable or even better hydration properties and emulsifying capacity compared to vegetable proteins, such as for example, soy protein. In addition, it has been proven that crickets have an excellent absorption capacity, which is considered a desirable functional property for meat products. Insects can therefore be used in the same way as plant proteins for processing meat products, as a functional food ingredient for the production of alternative meat products products or to partially replace raw materials of animal origin (lean meat and fats) in restructured meat products (Hyun-Wook et al., 2017).

In addition to the fact that insects serve as a source of food, they also provide many other valuable things products. It is known that a large number of different types of insects have remarkable commercial and pharmaceutical values. For example, it is common knowledge that

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bees and silkworms produce massive amounts of honey and silk. It is a well-known insect product also carmine – a red dye obtained from *Hemiptera* insects and used for dyeing food, textiles and pharmaceuticals. Resilin (protein), which enables insects to jump, is used in arterial repair medicine due to its elastic properties. In addition, they are known also other insect products such as propolis or royal jelly. At the same time, insects can also recycle organic waste (Tiencheu et al., 2017).

Stoops et al. (2017) state that insects can be consumed in various forms (natural form, paste, flour, extracts) and can also be part of various foods. For example, in Belgium and the Netherlands, foods are sold that contain insects either whole, or in the form of flour or extracts, while the content is not higher than 30 to 35%.

In the mass production of edible insects, it is necessary to create a production model on the basis of which it is possible to establish the most efficient breeding (high quality and quantity production, low investment and maintained well-being of farmed individuals). The basis for this model is knowledge of bionomics of insects reared in man-made conditions (Mangová et al., 2017).

1.2 The most commonly consumed types of insects

Among the most popular types of insects used for nutrition and feed production are species such as: domestic cricket (*Acheta domesticus*), two-spotted cricket (*Gryllus bimaculatus*), larvae (*Hermetia illuscens*) and 3 different types of worms (*Zophobas morio*, *Tenebrio molitor*, *Alphitobius diaperinus*) (Maciel-Vergara et al., 2017).

According to Van Huis et al. (2013), however, among the most commonly consumed worldwide insect species include: beetles (*Coleoptera*) 31%, caterpillars (*Lepidoptera*) 18%, bees, wasps and ants 14%. Followed by grasshoppers and crickets 13%, cicadas 10%, termites 3%, dragonflies (*Odonata*) 3%, flies (*Diptera*) 2% and other types of insects 5%.

Bednářová et al. (2013) on the basis of the research they consider to be the most suitable candidates for the use of entomophagy in our latitudes the following types of insects:

- argentine cockroach (*Blaptica dubia*),
- steppe cricket (*Gryllus assimilis*),
- domestic cricket (*Acheta domesticus*),
- honeysuckle (*Galleria mellonella*),

 DOI: https://doi.org/10.15414/2022.9788055225661

- silkworm (*Bombyx mori*),
- migratory locust (*Locusta migratoria*),
- omnivorous locust (*Schistocerca gregaria*),
- peruvian blackhead (*Zophobas morio*),
- *Tenebrio molitor*.

Domestic cricket (*Acheta domesticus*)

The house cricket has a light brown color. Adult individuals can reach a length of up to 16 – 21 mm. The first developmental stage is the egg, followed by the nymph and finally the adult an individual. It is typical for this type of insect that it is used as feed for insectivores all over the world for a very long time. At the same time, it is considered one of the best sources of protein insect base. Its content ranges from 70 g per 100 g of dry matter. Fat content represents approximately 20 g per 100 g of dry matter (Kulma et al., 2019), the fiber content around 18 16.4-19.1%. Of the fatty acids, linoleic acid predominates (30-40%), acid oleic (23-27%), palmitic acid (24-30%) and stearic acid (7-11%) (Abdalbasit et al., 2017).

In countries with long traditions of eating insects, such as Thailand, crickets are processed en masse for food purposes. It is currently available for purchase bread containing cricket flour in some European supermarket chains (Kulma et al., 2019), since last year, for example, also in the territory of the Czech Republic in Penny Market chains (Fig. 2).

Figure 2: Bread enriched with cricket flour

Crickets are eaten whole either as adults or as nymphs. Another possibility is the consumption of foods with the addition of cricket flour, which are considered the best

 DOI: https://doi.org/10.15414/2022.9788055225661

alternative. The protein content in the dry matter of an adult cricket varies within a range 55-70.7%, in dry weight of nymphs around 67-70.5% (Rumpold et al., 2013).

The house cricket is one of the most commercially bred insect species. Only in the United States, about 1,500 tons of crickets are produced annually. Breeding of this species insects is relatively undemanding. The main producer is Thailand, where it is located around 20,000 small cricket farms (Van Huis, et al., 2013).

Makkar et al. (2014) state that breeding crickets is possible at temperatures above 20 °C ideally, however, at 28-30 °C. Under these conditions, it is possible to breed approximately 2,000 individuals on an area of 1 m^2. The population is then itself regulated by cannibalism.

The subsequent processing is very individual depending on the type of processed insects. Dossey et al. (2016) present a model example of the processing of crickets of the *Acheta domesticus* species as follows: the crickets are killed, ground, pasteurized, dried and then they pack. Cricket meal companies either purchase live or frozen crickets from local breeders, or have their own breeding. Crickets are killed, ground to a size of approximately 100μm. Subsequently, the suspension is pasteurized at a temperature of 80 °C for 10 minutes in order to destroy the microorganisms present. They are then spray-dried and packaged into suitable packaging.

Cricket flour can also be made from roasted crickets crushed into powder. It can serve as a substitute for flour in many foods. The protein content of such flour is 5 times higher than in whole grain flour. Crickets are one of the most processed species insects, because they are resistant animals and their processing technology is the last has developed significantly over the past decade. At the same time, they are currently the most popular type for producing insect-based foods for the North American and European markets. The advantage is mainly that that such flour can be easily incorporated into many foods with little change in texture, appearance and taste, thus overcoming the initial aversion that consumers have to insect-based foods (Mason et al., 2018).

In study of Akullo et al. (2018), winged termite enriched crackers were most preferred, comparing favorably with the control. Increased substitution level significantly ($p<0.05$) decreased acceptability of crackers color. Nutrient content per 100 g increased significantly ($p<0.05$) with insect proportion, while nutrient quality reduced significantly ($p<0.05$) with increased temperatures; protein digestibility; 26.23 to 20.56% Fe; 42.26 to 20.79% and Zn solubility 27.63 to 18.32% at 90 and 150 °C respectively. Crackers enriched with 5% ground winged termite oven dried at 90 ^oC had good nutrient and sensory qualities.

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Tenebrio molitor

It is one of the most studied insect species ever. Also for this reason used as a model organism, due to its short life cycle and unpretentiousness breeding (Nowak et al., 2016).

It is a relatively widespread type of dark brown to black beetle that grows up to 12 – 18 mm in size. It often occurs near human dwellings, as far as it is concerned an important pest that feeds on flour and other grain products. Developmental the cycle of this type of insect lasts 2 to 3 months, depending on the temperature (Hurka, 2005).

This species goes through four developmental stages (egg, larva, pupa, adult individual). It is most often consumed in the larval stage, which lasts approximately 8-10 weeks. The size of the larvae reaches around 30 mm. The protein content at this stage varies from 47-76% in dry matter and a fiber content of around 9.55% (Rumpold et al., 2013), while the content 20 fat in the fresh state ranges from 16.6 to 22.3 g per 100 g. From amino acids isoleucine, leucine, lysine predominates, and of the fatty acids, oleic acid, acid linoleic and palmitic acid (Feng, 2018).

Argentine cockroach (*Blaptica dubia*)

This type of insect comes from Argentina and reaches a size of 4-4.5 cm. He's going of lightless insects that run very fast. Plastic boxes with dimensions 49x29x25 and a capacity of 1000 cockroaches. The suitable temperature for breeding is around 27 – 28 °C (Suchý et al., 2017).

The content of individual nutritional components is variable and depends on the developmental stage cockroaches. The protein content ranges from 47.5 to 54.3% and around 35.9 to 44.2% fat in dry matter. A high amount of unsaturated fatty acids is also typical for this species around 76%, while the content of saturated fatty acids is only 23.3% (Abdalbasit et al., 2017).

Migratory locust (*Locusta migratoria*)

The size of an adult varies between 33-55 mm, while females they are larger than males. This species is characterized by variable coloration of the body, which can be brown, gray, yellow-brown or green (Šefrová, 2006). They are characterized by a relatively short life cycle, reaching adulthood after 4-8 weeks, depending on breeding conditions. This species represents some rich resource proteins, fiber, but also essential fatty acids (Clarkson et al., 2018).

 DOI: https://doi.org/10.15414/2022.9788055225661

The protein content is approximately 62.2%, the fat content in the nymphs reaches 13% and the fiber 27%. Of the fatty acids, palmitic acid, stearic acid, oleic acid and linolenic acid (Kourimská et al., 2015).

Peruvian blackhead (*Zophobas morio*)

The Peruvian black beetle is, like the ground beetle, an ordinary inconspicuous black beetle; however, the size of the larvae reaches 4.5 cm before pupation (Bednářová et al., 2013). For purposes larvae or pupae are used for entomophagy. Adults are not consumed. Acts are 40 mm long worms, which have a grainy yellow color and one brown stripe. The body of these worms is covered with a thick chitinous skin, which can be worse in larger quantities digestible. The development cycle lasts approximately 4-6 months (Dossey et al., 2016).

Soares-Araújo et al. (2019) analyzed the nutritional composition of the Peruvian blackberry while they found that the protein content was approximately 46.8g per 100g of dry matter and the fat content represented 43.6 g per 100 g of dry matter. Of the mineral substances, magnesium with its content prevailed 39.1 mg per 100 g of dry matter and calcium up to 31.9 mg per 100 g of dry matter. The MUFA content represented 32.1% and PUFA content around 23.2% of the total fat content in the body.

1.3 Insects as animal feed

Every year, more than 1/3 of the world's total grain production is used as feed for farm animals, while this volume k could be used for feeding almost 3 billion people (Van Huis, 2015).

Suchý et al. (2017) consider it an indirect use of insects in human nutrition through animal nutrition, where individual types of insects are primarily used as protein components in feed mixtures. The authors believe that the larger the use of insects in livestock nutrition will be hindered mainly by economic aspects. Among the most promising insect species for industrial feed production are flies *Hermetia illucens*, housefly larvae (*Musca domestica*), silkworm larvae silkworm (*Bombyx mori*) and *Tenebrio molitor* worms. To a lesser extent, they are also suitable grasshoppers, crickets and termites (Suchý et al., 2017).

 DOI: https://doi.org/10.15414/2022.9788055225661

It is assumed that fisheries will supply up to 62% of the global supply of fish until 2030. This means that the demand for fishmeal and fish oils intended for feed purposes will also increase (IPIFF, 2018).

The current high demand and associated higher fishmeal/soybean prices together with increasing aquaculture production, they are pushing new research into the development of insect proteins for aquaculture and poultry. Insect-based feed products could have similar use such as fishmeal and soy, which are currently the most used. Researches indicate that insect-based feeds are comparable to fish-based feed mixtures flour and soy (Van Huis et al., 2013).

Another advantage of insects is their ability to recycle waste. For example, *Tenebrio molitor* larvae are able to recycle low-quality plant waste materials into high-quality ones feeds rich in energy, proteins and fats in a relatively short time. They are also capable detoxify the mycotoxin zearalenone by partially metabolizing it to its alpha-form. There is therefore no risk of accumulation of this mycotoxin in the larvae of *Tenebrio molitor* in such of a scale that could be dangerous for animals fed on this type of insect. Different types of grasshoppers are also used to feed live livestock condition (for free range chickens, pets, animals in zoos gardens) or in a dried state, ground (for broilers, fish) (Makkar et al., 2014).

It has been proven that the fly (*Hermetia illucens*) as part of a complete feed supports the growth of chickens, pigs and fish. In the case of grasshoppers, feeding experiments on certain ones species of fish confirmed that doses in which 25 to 50% of the fishmeal was replaced grasshopper meal, had the same results as rations containing 100% fish flour. In addition, it was demonstrated that all growth parameters of the selected fish species were higher in feed that contained grasshopper meal than in fed fish commercial feed types (Suchý et al., 2017).

1.4 Nutritional value of edible insects

Edible insects have a very diverse nutritional value mainly because there are large ones many types of edible insects. Their nutritional values can change within the same groups of insects depending on origin, stage of life, sex, but also on what it was insects fed. The nutritional composition is probably also influenced by the method of preparation insects (cooking, frying, baking, drying) before consumption. Insects have an increased level of protein content (Fig. 3), which represents the main component of their nutrient composition. They also contain

 DOI: https://doi.org/10.15414/2022.9788055225661

a significant amount of other important nutrients such as lipids, beneficial fatty acids, fiber (Ohara et al., 2018), but also vitamins such as riboflavin, pantothenic acid, biotin, folic acid and also minerals such as copper, zinc, iron, magnesium and phosphorus (Zielińska et al., 2018).

While the chemical composition and nutritional value of some edible insects have been determined (Finke et al., 1985; Bukkens 1997; Ramos Elorduy et al., 1997; DeFoliart et al., 2002; Paoletti et al., 2003; Kinyuru et al., 2013), there's still a dearth of information on nutritional quality of the most commonly consumed insects. Edible insect species are rich in proteins, amino acids, fats, vitamins and trace elements (Oyarzun et al., 1996; Paoletti et al., 2003; Banjo et al., 2006; Igwe, 2011; Ajayi, 2012; Ntukuyoh et al., 2012; Kinyuru et al., 2013). However, the nutrient levels reported vary greatly by species, environmental conditions, geographical location, feeding habits and the developmental stages of the insects (Defoliart, 1992; Verkerk et al., 2007; Srivastava et al., 2008; Raksakantong et al., 2010).

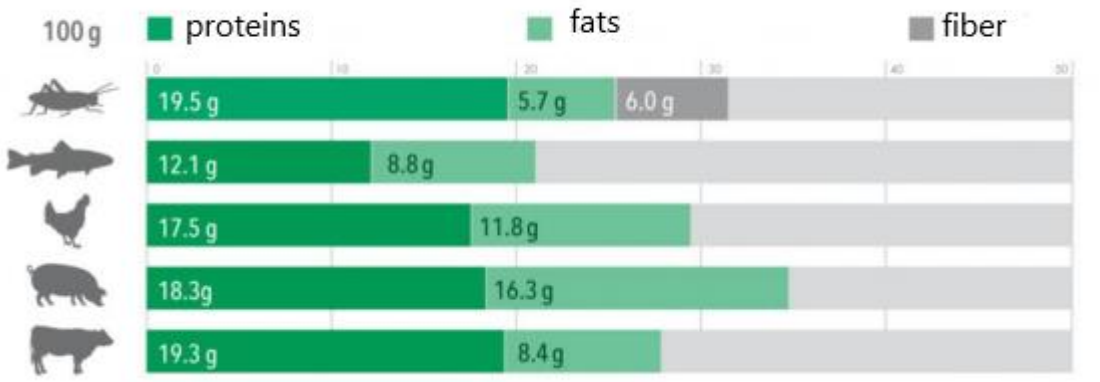

Figure 3: Nutritional values of selected species of animals' meat (Pavelková et al., 2018)

Energy value

The fatty acid content will represent the main source of energy value. It should be mentioned that this content is regarding the whole insect, since at the industrial level, there are flour forms in which the energy value is well below normal ranges. Insects, depending on many factors, will have an energy content between 200 (837 KJ) to 700 (2929 KJ) kcal.100 g^{-1} (dry basis), with the majority having an average value between 400 (1674 KJ) to 500 (2092 KJ) kcal.100 g^{-1} (Rumpold and Schlüter, 2015; Patel et al., 2019).

Several species of flies (*Diptera*) have low-fat content and their energy value oscillates between 200 (837 KJ) kcal.100 g^{-1}. In the order Lepidoptera, we can find species with high values that can exceed 700 (2929 KJ) kcal.100 g^{-1}, as is the case of the caterpillar *Phasus*

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triangularis with 776.9 (3251 KJ) kcal.100 g^{-1}. In general, we find many edible insects such as crickets, grasshoppers, locusts, and caterpillars in the range of 400 (1674 KJ) to 500 (2092 KJ) kcal.100 g^{-1}, varying according to the species and their nutrient content. No studies have been found where the energy value of insects of the orders Isoptera and Blattodea were reported, although it can be deduced that their energy value will be similar to the rest of the orders due to their fat and protein content (Rumpold and Schlüter, 2015; Patel et al., 2019).

The energy value of insects depends on their composition, mainly on the fat content. Larval stages are usually more energy-rich compared to adults. On the other hand, protein insect species have lower energy content (Kourimská et al., 2015). Table 1 shows the energy value of selected types of edible insects expressed in kcal.100 g^{-1} of fresh weight.

Table 1: Energy value of selected insects' species (FAO, 2012)

Latin name	**Stage**	**Location**	**Energy value (kcal.100 g^{-1})**
Chortoicetes terminifera	adult	Australia	499 (2088 KJ)
Oecophylla smaragdina	adult	Australia	1272 (5322 KJ)
Tenebrio molitor	larvae	USA	206 (862 KJ)
Tenebrio molitor	adult	USA	138 (577 KJ)
Atta mexicana	adult	Mexico	404 (1690 KJ)
Gryllus bimaculatus	adult	Thailand	120 (502 KJ)
Oxya japonica	adult	Thailand	149 (623 KJ)
Cyrtacanthacris tatarica	adult	Thailand	89 (372 KJ)
Bombyx mori	chrysalis	Thailand	94 (393 KJ)
Locusta migratoria	adult	Netherlands	179 (749 KJ)

Proteins

Proteins are the main component of insects. Content varies depending on of individual species contains a range from 7-91%, while most insects around 60% fat. However, it has been proven that in certain cases the protein content can also vary by more than 50% within the same species. It can result from external factors; such as are feed or ecology that can reach the final composition of the insect. Other factors, which influence the effect of the content are the stage of the insect's development and the method of its processing (Nongonierma et al., 2017).

In Mexico, 87 species of insects were studied and the average protein content of dry matter was listed from 15 to 81%. The study also examined the digestibility of insect proteins,

 DOI: https://doi.org/10.15414/2022.9788055225661

which represented 76-96%, which is on average only slightly less than egg white (95%) or beef (98%) and vice versa more than many vegetable proteins (Kourimská et al., 2015).

Regarding quality, Rumpold et al. (2013) state, that the protein of the house cricket (*Acheta domesticus*) is better than soy protein. It is typical for cereal proteins that they often have a low lysine content and in some sometimes lack of the amino acid tryptophan (corn) and threonine. In some insect species, these amino acids are very well represented. For example, some caterpillars from the Saturniidae family, the larva of Rhynchophorus ferrugineus and aquatic insects have a lysine content greater than 100 mg per 100 g of crude protein (Suchý et al., 2017).

It was also found that insect proteins have the ability to form gels depending on them concentrations and from pH that have potential for use as gelling agents or stabilizers in food (Bubler et al., 2016).

Mariod et al. (2013) extracted protein gelatin from two dried species insects (*Aspongubus viduatus, Agonoscelis pubescens*), while comparing this gelatin with commercially unique gelatin as a stabilizer in the production of ice cream. None were found Differences between ice cream made with the addition of classic commercial gelatin and gelatin obtained from insects.

According to Farin (2017), they could with the conventional food industry use the extracted proteins of insects in pre-prepared foods, such as salads or salamis that are familiar to the Western consumer.

According to Hyun-Wook et al. (2016), insect proteins can be used as a new source of proteins to partially replace the meat part in processed meat products without that nutritional and technological properties are compromised.

However, the measured amount of nitrogenous substances of insects can be higher than theirs real protein content, because a certain amount of nitrogen is also bound in the exoskeleton. The chitin content of commercially bred insects ranges from 2.7 – 49.8 $mg.kg^{-1}$ fresh weight and from 11.6 – 137.2 $mg.kg^{-1}$ of dry matter. It is known that chitin (like cellulose) is largely indigestible by humans. However, removing it improves digestibility of insect protein (Kourimská et al., 2015).

According to the World Health Organization (WHO): Edible insects overall meet the requirements for amino acids with high values for phenylalanine, tyrosine, tryptophan, lysine, and threonine. Specifically, species from the order Orthoptera, like crickets, are a good

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source of proteins and signify a valuable protein alternative. Most edible insects provide adequate amounts of essential amino acids required for the human body (Yi et al., 2013).

(Xiaoming, Ying, Hong and Zhiyong, 2010) analyzed the protein content from approximately 100 insect sources. The protein content was in the range 13 – 77% of dry matter and that there was large variation between and within insect orders. Since insect proteins have high amount of protein present, studies on optimum protein extraction methods can provide an alternative source of proteins to the food industry.

Fats

Insects use fats for various physiological functions, such as reproduction, development, flight, communication through pheromones, structure of cell membranes and others (Tzompa Sosa et al., 2017).

Fats are the second most represented nutrient in insects. Their representation fluctuates in the range of 7-77 g.100 g^{-1} of dry weight, depending on the species or diet. Larvae and pupae have a higher fat content compared to adults, probably because greater energy demand during development. Lipids consist of essential fatty acids such as linoleic acid and linolenic acid (Walia et al., 2018).

Lipids have a relatively high content of C18 fatty acids, including acid oil. Palmitic acid is also represented to a greater extent. The composition of fatty acids is influenced by the food that insects feed on (Kourimská et al., 2015).

Fat occurs in various forms in insects. TAGs make up approximately 80% of fat in insects and represent a reserve of energy for long flights. Phospholipids are the second most important group and their content is less than 20%. The most represented sterol is cholesterol (Tzompa-Sosa et al., 2014).

It was found that the average cholesterol content in the lipid fraction it was 3.6%. In addition to cholesterol, other substances such as campesterol, stigmasterol, β-sitosterol and other sterols were found (Kourimská et al., 2015).

The average caloric value of insects corresponds to fatty pork, because insects usually contain a large amount of fat, which, however, is of unsaturated fatty acids resembles fish oil. A significant share of unsaturated of fatty acids is characterized by the fat of the larvae of the small mealworm (Borkovcová, 2015).

The high fat content is particularly typical for all types of caterpillars. Top content of fat was measured in the caterpillar of the butterfly Phassus triangularis with a value of 77 wt. %.

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The lowest fat content was found in the larva of Oryctes boas, only 1.5 wt. % (Banjo et al., 2006).

In fats extracted from insects, the main types of lipids are triacylglycerols, which reflect the original composition of lipids in insects. The presence of other compounds depends on extraction process. The extraction process itself does not affect the content of fatty acids strongly influences the extraction yield and types of extracted lipids. For example, when water extraction is used, only triacylglycerols are extracted. But if organic is used solvents, phospholipids, partially glycerides and triacylglycerols are obtained (Tsompa Sosa et al., 2017).

It has been proven that oils extracted from insects are rich in polyunsaturated fatty acids and often also contain the essential fatty acids linoleic and α-linolenic. The representation of fatty acids in insects is mainly influenced by the plants that the insects eat lives. The presence of unsaturated fatty acids leads during the processing of insects to rapid oxidation with subsequent swallowing (Suchý et al., 2017).

Edible insects also contain an average of 10–68% of fat on dry matter basis (Tzompa-Sosa et al., 2014).

Mineral substances

Edible insects can also be nutritionally interesting in terms of their mineral content (Fig. 4) such as iron, zinc, potassium, sodium, calcium, phosphorus, magnesium, manganese and copper. Content of individual macroelements and microelements varies greatly between species and is significant also affected by their content in the feed substrate (Suchý et al., 2017).

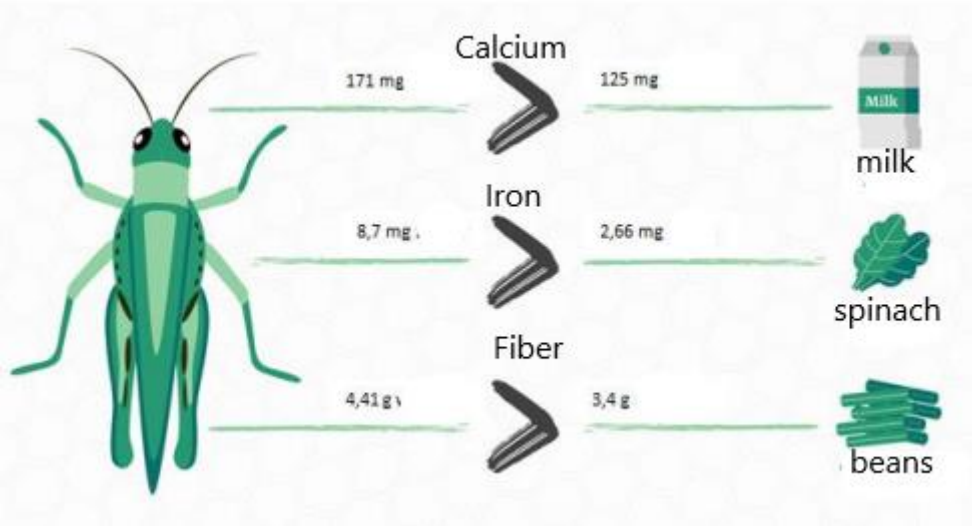

Figure 4: Nutritional value of crickets compared to ordinary foods, calculated per 100 g (URL 3)

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Insects contain a higher percentage of iron, zinc and calcium than pork and beef and chicken. The iron content in beef is around 6 mg per 100 g of dry matter, in pork it is about 1.5 mg and in poultry about 1.2 mg per 100 g. Iron content in the desert locust (*Schistocerca gregaria*) it is 8.38 mg per 100 g and in Mopana caterpillars up to 31-77 mg per 100 g of dry matter. At the same time, these caterpillars are also a good source of zinc (14 μg per 100 g of dry matter), as well as larvae of *Rhynchophorous phoenixes* (26.5 μg per 100 g dry matter) (Kourimská et al., 2015).

The calcium content is also very interesting. By comparison, beef contains on average 4-27 mg of calcium per 100 g of dry matter, pork 5-28 mg and only poultry 5-14 mg per 100 g, while the calcium content in the body of *Grylodes sigillatus* (cricket short-winged) is around 170 mg per 100 g, in the desert locust 70 mg per 100 g and in *Tenebria molitor* 40 mg per 100 g (Zielińska et al., 2015).

Insects are a good source of many minerals. According to Rumpold and Schluter (2013), most edible insects have high levels of phosphorous that meet adults' dietary requirements. The authors and Kohler et al. (2019) also reported that several insect types provide significant amount of magnesium, especially crickets, locusts and grasshoppers. Insects are also generally regarded as good sources of manganese, copper, selenium, zinc, iron and calcium. In fact, edible insects have been shown to contain more calcium, zinc and iron than chicken, pork and beef (Sirimungkararat et al., 2010) which means that entomophagy can be considered as an alternative source of minerals to beat 'hidden hunger' prevalent in most developing countries (Gibson, 2015) where prevalence of persons at risk of zinc deficiency, for instance, stands at 17% (Gibson, 2015) while those at risk of iron deficiency stands at 25% (McLean et al., 2009). The low levels of sodium in edible insects means that this food type can be readily and conveniently incorporated in low sodium diets for high sodium sensitive individuals (Rumpold and Schluter, 2013).

Vitamins

According to Suchý et al. (2017) insects contain a whole range of vitamins such as vitamins of group A, D, E, K, C and vitamins of group B. It is also very favorably represented thiamine, which is 0.1 – 4 mg.100 g^{-1} of dry matter. Riboflavin is represented in quantity 0.11 – 8.9 mg per 100 g of dry matter. For comparison, the authors state that whole grain bread 28 it contains only 0.16 mg of thiamine and 0.19 mg per 100 g of riboflavin. Vitamin B_{12}, that is found only in foods of animal origin and is well represented in the larvae of the whitefly

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common (*Tenebrio molitor*) 0.47 μg.100 g^{-1} and domestic cricket (*Acheta domesticus*) 5.4 μg per 100 g in adults and 8.7 μg.100 g^{-1}in nymphs. Retinol and β-carotene have been found, for example, in some species of caterpillars butterflies (*Imbrasia oyemensis, Nudaurelia oyemensis, Imbrasia truncata*).

Retinol content represented 32 – 48 μg.100 g^{-1}dry matter and the β-carotene content was around 6.8 – 8.2 μg.100 g^{-1}. In worms species *Tenebrio molitor* and crickets (*Acheta domesticus*) was the level of retinol per 100 g dry matter lower than 20 μg and β-carotene level lower than 100 μg (Kourimská et al., 2015).

Insects are generally rich in a wide range of vitamins including riboflavin, biotin and pantothenic acid. Grasshoppers, locusts, beetles and crickets are particularly rich in folic acid. Although other type of vitamins occurs in relatively low amounts, it is hypothesized that vitamins concentration in edible insects can be influenced by and/or controlled through feed manipulation (Pennino et al., 1991).

1.5 Preparation and technological processing

According to Ramos Fraquez et al. (2017) the processing and storage of insects and products from them should be governed by the same health and hygiene regulations as apply to any other traditional food or feed to ensure safety food. Considering their biological composition, it is necessary to consider several questions such as microbial safety, toxicity, taste and presence of inorganic compounds.

Suchý et al. (2017) state the basic model of insect processing as follows:

- separation from the substrate (sieving),
- storage (freezing, drying, loading into special pickles),
- treatment before consumption (mechanical treatment, grinding - better after heat treatment),
- treatment to prevent browning or blackening,
- separation of individual nutrients (protein, fat, chitin and others).

It is advisable to feed the insects with suitable fresh food for about a week. During this time, the insect expels from its body the remains of everything it ate before. The very choice of feed it depends on the taste of the insects we want to achieve. It is then left for about 2 – 3 days

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starve to clean the digestive system. Such insects are then collected and selected only healthy, active individuals (Borkovcová et al., 2009).

Preparation before processing in large-scale farms includes cleaning and storage insects. The next step is cooling, which is commonly used as a pretreatment step. It keeps the insects alive and at the same time immobilizes the more mobile types of insects, because it will happen to knock out some nerve centers. For example, temperatures of 0 – 5 °C are used for larvae (*Hermetia illucens*) and common whitefly (*Tenebrio molitor*), while temperatures 5 – 10 °C are mainly used in the processing of crickets (IPIFF, 2018).

Borkovcová et al. (2009) state that in many countries of the world insects are consumed immediately after catching. In the case of further processing, the best method is theirs humane killing by throwing live insects into hot oil or boiling water. However, insects are killed only just before preparation, because just like fish, it undergoes decomposition processes very quickly and can already several hours after killing contain pathogenic organisms.

In large-scale farms, the killing of insects is carried out in different ways, depending on the situation from farmed species. For example, worms and crickets are usually killed with hot water or with boiling steam. Flies (*Hermetia illucens*) are directly ground or exposed the effect of increased temperature. Microwaves and infrared can also be used for killing tunnels or freezing. In this case, however, processing parameters such as time would the exposures or the thickness of the insects should be adapted to the individual farmed species. Another one step is lyophilization, which removes excess water from the insects before grinding. This one the technique consists of maintaining a low temperature to dehydrate the insects using sublimation. Depending on the used method of killing, the insects can still be dried out prevented possible microbiological contamination (IPIFF, 2019).

Grinding fresh insects is mechanically complicated and accompanied by the formation of sludge, which results in impaired storability and subsequent processing. Therefore, it is very important drying of insects. The main goal of drying is to reduce the water content to 5-10% (Tzomba Sosa et al., 2017).

The next steps are either milling or extraction. For many purposes and mainly for the production of protein-rich insect additives, it is fat extraction and grinding into smaller particles is a prerequisite. Particle size of the final powder has a significant impact on the technological properties of insect-based additives, for example, on dispersibility, solubility and rheological properties during rehydration. From that for this reason, grinding conditions must

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be carefully chosen according to the species, especially if it is processed adult insects (crickets, grasshoppers) rich in chitin and with a structured exoskeleton (Tzomba Sosa et al., 2017).

Fractionation is considered a promising strategy for the production of standardized insect-based intermediates. The process consists of the application of physical, chemical and biochemical processes for the extraction of proteins, fat/oil, chitin and other derivatives from insects, for example chitosan and glucosamine. It can be used to obtain oil/fat mechanical operations (pressing), heat treatment or organic solvents. On the obtaining chitin from insects uses chemical or enzymatic processing (Purschke et al., 2018).

According to Tzomba Sosa et al. (2017), wet fractionation has been proposed so far, although in principle dry fractionation can lead to better quality and is not necessary at the same time remove water after extraction. Proper packaging is also very important.

Ramos Fraqueza et al. (2017) state that due to the high fat level of most types of insects and especially the amount of mono and polyunsaturated fatty acids should be packaged in a modified form atmosphere to prevent lipid oxidation or to slow down their oxidation.

The taste of insects is also a very important feature, which is very diverse (Tab. 2). It is influenced mainly by pheromones that occur on the surface of insects. Besides, it is also influenced by the environment in which the insect lives and also by the food it feeds on. Selection feed can be adjusted according to how we want the insects to taste. As long as it is an insect tanned, it is practically tasteless, because the pheromones are also washed away (Kourimská et al., 2016). However, according to Borkovcová et al. (2009) it is also an advantage, because insects subsequently it takes on the flavors of the added ingredients. The authors state that the larva of the common whitefly (*Tenebrio molitor*), which lives in flour, tastes like bread, while aquatic insects also have a taste the smell of fish.

Table 2: Taste characteristics of insects (adjusted according to Kouřimská et al., 2015)

Insects	**Taste**
ants, termites	sweet, almost nutty
caterpillar larvae	whole wheat bread
larvae of wood-destroying beetles	fatty belly with skin
larvae of dragonflies and other aquatic insects	fishy
cockroaches	mushrooms
wasps	pine seeds
worms	fried potatoes
Pyrgus caterpillars	cracklings

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Insects are often eaten whole, but they can also be processed in the form of granules or pastes. It is also possible to extract proteins, fats, chitin, minerals and vitamins from it. However, these extraction processes are currently too expensive and will continue to be needed develop so that they are profitable and applicable for industrial use in the food industry and the forage sector (Van Huis et al., 2013).

According to Khalaf et al. (2018) is the best strategy to promote increased consumption insects its unrecognizable incorporation into various known products.

1.6 Legislation

The regulatory frameworks governing the food and feed chains have significantly expanded in the last 20 years. However, the regulations that determine the insects as a source of food and feed, they are still largely lacking. In developed countries it is one of the main limiting factors that prevent the industrial development of breeding insects, the absence of clear legal regulations and standards that enable the use of insects as food or feed (Van Huis et al., 2013).

Currently, the regulation on novel foods (regulation 2015/2283) entered into force in January 2018. Any entity that wants to sell insects for human consumption in the EU, must go through the EFSA approval process (European Food Safety Authority). While the EFSA to individual commodities expresses, it is possible until 2020 to offer insects for human consumption on the basis of the above exceptions. This legislation therefore gives EU states the opportunity to start using insects in the food industry. The creation of rules for the breeding and consumption of insects will already depend on to each member state separately (González et al., 2018).

The opinion of the Office of Public Health of the Slovak Republic states that insects belongs to the group of so-called of "new foods", i.e. foods that were not substantially used for human consumption before 15 May 1997 in any of the Member States countries of the European Union. All specific insects will be prior to placing them on the market EU as food assessed whether it is a "new foods" and as a "new food" they will have to be entered in the Union list in accordance with the procedures indicated in Regulation (EU) No. 2015/2283. However, no species is listed in this list yet insects - as an authorized new food in the EU. However, in the process of assessment at the EU level there are currently applications for the approval of

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new foods related to insects, e.g. larvae (Alphitobiu diapernius), dried mealworms (*Tenebrio molitor*), dried crickets (*Gryllodes sigillatus*) (URL 4).

1.7 The risks of entomophagy

Growing interest in insects as food, supported by many potential benefits increases the need for a clear and comprehensive legal framework at the international level level. In 2015, the European Commission requested the ESFA on this specific issue o review current knowledge about various risks associated with production and by eating insects. No serious suspicions concerning the safety of this alternative food source were found, since the risks of using insects are not greater than the risks associated with other animals. In particular, it is considered the main danger handling and storage of farm-raised insects than the insect species itself (La Barbera et al., 2018).

The risks associated with entomophagy are mostly caused by eating insects in inappropriate stage development, incorrect handling of insects and inappropriate treatment. For example, eating grasshoppers without removing the legs can result to intestinal blockage, which can have fatal consequences (Kourimská et al., 2016).

Collecting insects in large numbers in the wild could also mean serious intervention in the country's ecosystem. In addition, insects obtained in this way pose a higher risk of infection various pathogenic organisms. Insects are bred in European insect farms in closed boxes where the atmosphere, feed and water are controlled. They are not during breeding used hormones, antibiotics or other chemical substances. However, if it is a free-living insect in nature, it is never possible to guarantee complete safety (EFSA, 2015).

Therefore, it is recommended to consume farm-raised insects under controlled and defined conditions. The correct selection of suitable and safe feed is also important, which we will ensure subsequent health safety of edible insects (Kourimská et al., 2015). As inappropriate the feeding of insects with bran, in which there is a higher concentration of heavy metals, has been demonstrated (Bednářova et al., 2010).

Allergies and poisonings

As with any new food, the introduction of insects into menus can pose a risk of food allergy. Food allergies are an important problem, because they affect approximately 5% of

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the population and can result in serious or even life-threatening reactions. New foods contain proteins capable of sensitizing and triggering allergic reactions that have not yet been identified due to insufficient exposure (Dossey et al., 2016).

Some insects have a solid outer covering of the body containing chitin, which it is difficult for people to digest. Currently, due to the lack of foods containing chitin there is also a lack of the chitinase enzyme that breaks down chitin. Some individuals have such small ones the amount of this enzyme, that eating insects can cause an allergic reaction to them. The most at risk are those who are allergic to seafood such as shrimp and crawfish (EFSA, 2015).

Even the presence of pathogens containing chitin can in some more prone individuals to cause the formation and development of nasal polyps (Park et al., 2009).

Particular attention should be paid to the microbiological hazard associated with the consumption of edible insects. Insects are a rich source of nutrients and moisture and therefore provide a favorable environment for microbial growth. For example, some were found cases of botulism and other diseases related to the consumption of insects stored in bad conditions in Africa. It is also not suitable to eat whole insects with them intact digestive tract, which can significantly increase microbiological risks (Caparros Megido et al., 2017).

The intestinal microbiota of insects represents a suitable environment for the growth of undesirable microorganisms. Based on microbiological research on the content of fresh, processed and stored insects of the species *Tenebrio molitor*, *Acheta domesticus* and *Brachytrupes* have been shown to be detected and later isolated in fresh insects various types of bacteria of the *Enterobactericeae* family and also sporulating bacteria that infect insects they most likely get it when in contact with the soil (Reineke et al., 2012).

However, pathogenic insect bacteria are generally considered harmless to humans and other animals, as they mainly represent bacteria that naturally live in insects they do not find, but which they acquire during life (rearing conditions) (EFSA, 2015).

As a result, eating raw insects should be avoided and strongly discouraged recommends treatment by sterilization, pasteurization, blanching (immersion in hot water from 80 to 100 °C) or roasting (Caparros Megido et al., 2017).

Toxicity

According to Kouřimská et al. (2016) some insect species can produce or contain (as a result of consuming poisonous food) strong pharmacological compounds, which are known

 DOI: https://doi.org/10.15414/2022.9788055225661

vertebrate toxins. However, the biggest problem is represented by substances that they retain their toxicity even after heat treatment.

Insects are also able to synthesize natural toxins in the production of defensive ones chemicals. These defensive secretions include carboxylic acids, alcohols, aldehydes, alkaloids, ketones, esters, lactones, phenols, 1,4-quinones and steroids. That is why it is important to choose the correct species of insects in the appropriate metamorphic stage based on their ability to produce natural toxins (Van der Spiegel, 2016).

A well-known example is solanine, which passes into the bodies of mandeline larvae potato beetle (*Leptinotarsa decemlineata*) - a well-known pest of potatoes. These larvae are subsequently poisonous to humans (Borkovcová et al., 2009).

Van der Fels-Klerx et al. (2018) consider insects to be the main way of exposure chemical danger is through the substrate on which insects breed. The authors state that potential accumulation often depends on the insect species and its developmental stage at which insects are collected. Among the most important element due to its accumulation potential there is cadmium and arsenic in insects.

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2 AIM OF THE WORK

After studying the domestic and foreign literature, the aim of the practical part was the following:

- compare the composition of sausages made with 2 and 4% addition of cricket flour with control samples without the addition of flour and find out the differences in the individual parameters,
- quality parameters using physical-chemical and sensory analysis, evaluate the possibility of using cricket flour in the production of sausages and its effect on resulting physico-chemical and textural properties.

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3 MATERIAL AND METHODS

3.1 Object of research

For evaluation purposes, we made sausages (Fig. 5) with the addition of cricket flour (*Acheta domesticus*) in the amount of 2 and 4% per 1 kg of meat. A variant was made without the addition of flour, which served as a control, then samples of the experiment with 2% addition of cricket flour and 4% addition of cricket flour to the meat part. The produced sausages were then packed in artificial casings and part of it was also vacuum packed. After production, the sausages were marked for for easier orientation by the relevant brand and stored in a refrigerator at a temperature of 2-4 °C.

Figure 5: Sausages with addition of cricket flour

3.1.1 Cricket flour

Cricket flour made from domestic cricket (*Acheta domesticus*) was purchased online through SENS Food Ltd. from a cricket farm based in London. It is a company with a production capacity of 3.5 tons of cricket flour per month, which ranks it to the largest processors in the world. The flour was delivered in a 1 kg package in an aluminum bag 37 and stored at ambient temperature. Manufacturers state that it is already in 100 g of flour approximately 1100 ground crickets.

The manufacturer also states that the crickets were kept in boxes with a height of up to 6 m in a controlled environment and were fed plant-based feed. After 4 weeks, crickets were

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killed by freezing, which put them in a state of hibernation. Technological processing is not specified by the manufacturer.

On its website, the manufacturer lists the nutritional composition of cricket flour per 100 g of the product (Tab. 3) and information that people who are allergic to seafood can have allergic reaction to crickets.

Table 3: Nutritional composition of cricket flour

Nutritional values per 100 g of product	
Energy (kcal, KJ)	440 (1841)
Carbohydrates (g)	4
Fats (g)	17.8
Proteins (g)	66
Vitamin B_{12} (µg)	23
Ca (mg)	433
Fe (mg)	168
Na (mg)	17

3.1.2 Manufacturing of sausages

The production of sausages took place in the premises of the Department of Evaluation and Processing of Animal Products. For production, we used 5 kg of pork shoulder and 5 kg of pork side. The raw materials were first cut into smaller parts, ground and divided into 3 parts of 3 kg each. Appropriate spices and water in the form of flake ice were added to the raw material prepared in this way and ingredients according to the recipe.

The recipe for making sausages for 3 kg of meat was as follows:

- nitrite salting mixture 60 g,
- ground black pepper 4.5 g,
- ground sweet pepper 6 g,
- ground hot pepper 6 g,
- nutmeg 1 g,
- garlic 3 g,
- breeze 24 g.

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We did not add cricket flour to the first part of the work, so it served as a control sample. We added 2% cricket flour to the second part and 4% cricket flour to the third part. After adding all the raw materials, cutting took place until we reached a homogeneous mixture consistency and subsequent filling into artificial intestines and labeling of samples. The sausages were smoking and then the product was heat treated so that it was achieved in all parts temperature of the product at 70 °C for about 10 minutes. The products were cooled, while the part was wrapped vacuum and stored in a refrigerator until the time of analysis at a temperature of around 4 °C.

Individual samples were subjected to analyze on different days. In the case of vacuum packaged sausages on the 1^{st} – 7^{th} – 14^{th} day after production, while fresh samples (packaged only in artificial intestines) were analyzed from 1 – 4 to 7 – 10 days from production. Individual samples were taken out of the refrigerator just before the analyses.

3.2 Methodology

3.2.1 Methods of determining physico-chemical parameters

For the purpose of qualitative evaluation of products, we focused on determining content of sodium chloride (NaCl) argentometrically, fat, water, pH value and color of sausages.

Determining content of NaCl

Principle

From the pre-homogenized sample, an extract is prepared using water in which they are determined total chlorides by titration with $AgNO_3$ to potassium chromate indicator (5%). Result is subsequently recalculated according to the formula for sodium chloride.

Process

2 g of the homogenized sample were weighed with an accuracy of 0.1 g into the prepared dry titration flask with a volume of 250 cm^3, heated distilled water in the amount of 100 cm^3 was added and the sample was mixed thoroughly. The sample thus prepared was allowed to infuse approximately 30 minutes (the sample was mixed several times). Subsequently, about 2 cm^3 was added 5% potassium chromate solution titrated with silver nitrate solution ($AgNO_3$) of a slightly red color, which did not disappear after stirring for half a minute.

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Calculation

$$\% NaCl \text{ in sample} = \frac{\text{usage of } AgNO_3 \text{ during titration}}{2}$$

Determination of fat content by the butyrometric method

Principle

The principle of this method consists in breaking down proteins using sulfuric acid at the same time separation of fat in the butyrometer scale due to the acting centrifugal force. Get fat then readings on the scale of the butyrometer used: in mass percentages.

Process

A pre-homogenized sample of sausages is weighed on the prepared cellophane in the amount of 5 g with an accuracy of 0.01 g. Subsequently, the weighed sample together with the cellophane is placed in of the butyrometer, it is corked, turned and placed in the prepared stand. Subsequently, it is added to the upper ones with a narrower opening of 10 cm^3 of gerberic acid, which is still layered with 10 cm^3 of water added along the butyrometer wall. Finally, 1 cm^3 is added of amyl alcohol and butyrometer closes with a stopper. The butyrometer prepared in this way is shaken to dissolve it individual non-fat parts, put in a centrifuge and spin for 5 minutes at 1200 rotations per minute. After centrifugation, the butyrometer is removed and the contents are read fat from the butyrometer scale. If necessary, the fat (lighter) column can be adjusted by moving the rubber plug to the zero point of the scale. Difference of results between parallel determinations must not exceed a difference of 0.75%.

Determination of pH

A desktop pH meter Orion Star A211 from the company Thermo Fisher Scientific was used to determine the pH value. Before use, the device was calibrated to pH 4 and pH 7, respectively the temperature of the sample was measured and the temperature on the device was set according to it. We value the pH obtained by perpendicularly inserting a glass electrode into the sample, while we did 4 repetitions for each sample. Individual pH values were recorded after stabilization on the device display.

 DOI: https://doi.org/10.15414/2022.9788055225661

Determination of water content

Principle

The essence of the method consists in rapid drying of the sample at a temperature of around 170 °C, while it is only an orientation method.

Process

The analyzed sample is homogenized. Used glass bowls together with glass ones with sticks, it is weighed to the nearest 0.01 g. Subsequently, approximately 10 g is weighed into them samples with an accuracy of 0.01 g. After weighing with the help of a moistened glass rod with ethanol, spread the sample evenly over the entire surface. Samples prepared in this way are they are moved to a heated oven (170 °C) where they are dried for 45 minutes. The samples are then they are allowed to cool in a desiccator and weighed on scales with an accuracy of 0.01 g.

Calculation

$$x = \frac{100 \times (a - b)}{a - c}$$

x = water content in the analyzed sample in mass %

a = weight of the dish, inserted rod a: sample before drying (g)

b = weight of the dish, inserted rod and sample after drying (g)

c = weight of the bowl, inserted stick before weighing the sample (g)

Determination of colour

A spectrophotometer CM - 2600D from the company Konica Minolta was used to determine the color of the sausages, which makes it possible to express color in the CIELab color environment. In this environment, color is defined as a point in three-dimensional space depending on the coordinates L*, a* and b*.

L* represents the lightness of the color (luminance). It is located on the vertical axis in space and its value ranges from 0 (black) to 100 (white). The color coordinates a* and b* represent values from which the saturation and hue of the color can be calculated. a* is part of the spectrum wavelengths that correspond to colors from green(-a*) to red (+a*), b* again corresponds to colors from blue (-b*) to yellow (+b*) (Saláková, 2012).

 DOI: https://doi.org/10.15414/2022.9788055225661

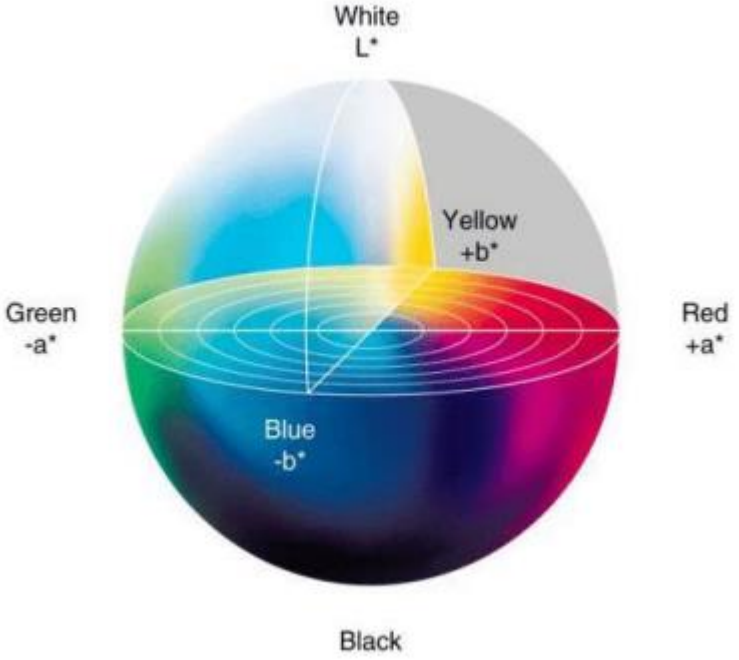

Figure 6: Cross-section through the color space CIEL*a*b* (URL5)

Determination of protein and cholesterol content

The analysis of proteins was performed using an Infratec 1265 Meat Analyzer (Foss) which operates from 850 to 1,050 nm at 2 nm intervals. Meat samples were placed into a glass cup of 130 mm diameter and the average spectra of 15 scan locations was recorded as log 1/*T* (transmittance). The values were expressed as g.100 g^{-1} (wet basis).

The samples were analysed for cholesterol content by the spectrophotometric method as previously reported by Horňáková, Chromý and Heyrovský (1974).

3.2.2 Method for sensory analysis

The sensory evaluation took place on the 7th day after production. Individual samples were pre heat-treated (by boiling) for approximately 5 minutes and then cut into smaller parts. The evaluation took place at the Department of Animal Evaluation and Processing products in the sensory laboratory, and was attended by 5 evaluators from the student council Department of Food Technology. The evaluators had a point scale of 1 – 6 at their disposal, while 1 represented the lowest rating and 6 the highest rating. Individual samples were given to the evaluator gradually. They were evaluated both fresh (not vacuum-packed) and vacuum-

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packed packaged samples with different additions of flour (P1 = 2% and P2 = 4%) together with the control sample (K) without the addition of flour.

The evaluated parameters were:

- smell,
- taste,
- juiciness,
- delicacy and fragility,
- colour.

3.3 Statistical evaluation of results

The initially obtained results from the experiments were subsequently evaluated in the program SAS version 9.3. using application, the Enterprise Price Guide 4.2, 2008. From the results basic descriptive statistics was calculated by the program and for the detection of statistically significant differences, the Wilcoxon test was used at the level of significance $p<0.05$.

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4 RESULTS AND DISCUSSION

The essence of the performed analyzes was the observation of differences between the samples of the experiment with 2 and 4% addition of cricket flour and control samples without the addition of cricket flour with a focus on individual batches in fresh condition (packaged only in artificial casings) and vacuum-packed (packed in artificial casings and subsequently also vacuum-packed).

4.1 Results of determination of physical and chemical parameters

4.1.1 Content of NaCl

Table 4 shows the measured values of the NaCl content in the samples during individual measurements. Average NaCl contents for individual groups of sausages are shown in Table 4.

Table 4 shows that the measured values of the NaCl content in the samples ranged from 1.41 (P1V – 1st day) to 2.55% (KC – 10th day). In a group of fresh sausages, we can see the rising tendency of the NaCl content in the analyzed samples over time. The increase in salt content was caused by higher loss of water and thus an increase in dry matter and fat content. On the contrary, in the group of vacuum-packed sausages the values were stable and the increase occurred up to the 14th day after production, while the NaCl content in the control sample increased more significant. Higher NaCl content in control samples was detected in all monitored periods.

Average values in the group of control samples (KV, KC) varied from 1.45 (KV – 1st day) to 2.55% (KC – 10th day). In the case of sausage samples packaged only in artificial casings, there was a significant rise in the NaCl value compared to the group of vacuum-packed sausages.

Average values in the samples of the experiment with 2% addition of cricket meal (P1V, P1C) ranged from 1.41 (P1V – 1st day) to 2.25% (P1C – 10th day). Aye in this case, there was a more significant increase in NaCl content in the case of sausage samples packed only in artificial casings. Average values in the samples of the experiment with 4% addition of cricket flour (P2V, P2C) ranged from 1.46 (P2V – 1st and 14th day) to 2.12 (P2C – 7th day). Again there

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was a more significant rise in values depending on time in the group of sausages packed only in artificial intestines.

Table 4: Average NaCl content in sausage samples in %

Sample	Day	Average ± *S.D.*
KC	1	1.75 ± 0.03
	4	1.92 ± 0.03
	7	2.40 ± 0.03
	10	2.55 ± 0.53
P1C	1	1.49 ± 0.03
	4	1.65 ± 0.04
	7	2.22 ± 0.03
	10	2.25 ± 0.52
P2C	1	1.60 ± 0.03
	4	1.59 ± 0.03
	7	2.12 ± 0.04
	10	2.07 ± 0.51
KV	1	1.45 ± 0.03
	7	1.49 ± 0.09
	14	1.70 ± 0.03
P1V	1	1.41 ± 0.07
	7	1.47 ± 0.06
	14	1.51 ± 0.04
P2V	1	1.46 ± 0.04
	7	1.47 ± 0.03
	14	1.46 ± 0.04

Notes: KC – control group packed in artificial casings with 0% addition of cricket flour, P1C – experimental group packed in artificial casings with 2% addition of cricket flour, P2C – experimental group packed in artificial casings with 4% addition of cricket flour, KV – vacuum-packed control group with 0% addition of cricket flours, P1V – experimental group vacuum packed with 2% addition of cricket flour, P2V – experimental group packaged vacuum with 4% addition of cricket flour

Average values in the group of non-vacuum-packed sausages (Tab. 4) varied ranging from 1.49 (P1C – 1st day) to 2.55% (KC – 10th day). The table shows that it happened to a more

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significant rise in NaCl content depending on time, while the highest values were found in the case of control samples without the addition of cricket flour.

In the group of vacuum-packed sausages (Tab. 4), the average values varied ranging from 1.41 (P1V – 1st day) to 1.70% (KV – 14th day). Unlike the sausage group packed only in artificial casings, vacuum-packed samples did not show more significant increase in NaCl content values depending on time. Differences between individual samples were only minimal, except on the 14th day after production, when there was a significant increase in the content NaCl in the control sample.

Based on the Wilcoxon test at the level of significance (P>0.05), none was demonstrated the difference between the measured NaCl values.

4.1.2 Protein content

Table 5 shows the detected average values of the fat content in the samples. The protein content in the samples ranged from 18.97% (KV – 7th day) to 25.35% (P2C – 10th day). Table 5 shows that the highest protein content was reached in the samples of the experiment P2C and P1C on the 1st day. The table also shows that the protein content was overall higher in the group of fresh sausages than in the group of vacuum-packed sausages.

Table 5: Protein content in the sausages samples

Sample	Day	Average ± *S.D.*
KC	1	19.36 ± 0.03
	4	19.54 ± 0.05
	7	19.58 ± 0.14
	10	22.11 ± 0.07
P1C	1	19.56 ± 0.02
	4	20.98 ± 0.06
	7	21.19 ± 0.05
	10	22.85 ± 0.15
P2C	1	19.65 ± 0.04
	4	21.09 ± 0.09
	7	21.49 ± 0.06

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	10	25.35 ± 0.10
KV	1	19.40 ± 0.04
	7	18.97 ± 0.06
	14	19.05 ± 0.04
P1V	1	19.75 ± 0.05
	7	19.73 ± 0.05
	14	19.25 ± 0.04
P2V	1	19.89 ± 0.04
	7	19.58 ± 0.10
	14	19.56 ± 0.05

Notes: KC – control group packed in artificial casings with 0% addition of cricket flour, P1C – experimental group packed in artificial casings with 2% addition of cricket flour, P2C – experimental group packed in artificial casings with 4% addition of cricket flour, KV – vacuum-packed control group with 0% addition of cricket flours, P1V – experimental group vacuum packed with 2% addition of cricket flour, P2V – experimental group packaged vacuum with 4% addition of cricket flour.

In the group of fresh sausages, we observed an increasing tendency of protein content in both experimental and control samples. The protein content increased with decreasing water content in these samples and reached up to 25.35% in the P2C group on the 10th day.

In the group of vacuum-packed sausages (Fig. 10), we can see a smaller fluctuation in the values of the fat content compared to the group of fresh sausages. In the case of vacuum-packed samples, the protein content decreased slightly depending on time. The lowest protein content was found in the KV sample on the 7th day after production, where the observed sample contained only 18.97% protein.

The average values of protein content found in the groups of control samples (KV, KC) ranged from 18.97% (KV – 7th day) to 22.11% (KC – 10th day). In the case of samples packed only in artificial casings, higher protein content was found depending on the storage time compared to the group of vacuum-packed sausages. In the control group of vacuum-packed sausages, the highest protein content value of 19.40% was found on the 1st day after production.

In the experimental samples (P1V, P1C), the average values ranged from 19.25% (P1V – 14th day) to 22.85% (P1C – 10th day). In the group of sausages packed only in artificial casings, there was an increase in protein content depending on time; on the 1st day after production, the average fat content was found to be 19.36%, while on the 10th day, a value of up to 22.11% fat was found. In the case of vacuum-packed sausages, there was a slight decrease

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in fat content on the 14th day after production compared to the 1st day after production (19.75%), where the average fat content was found to be 19.25%.

The average protein content in the experimental samples (P2V, P2C) ranged from 19.56% (P2V – 14th day) to 25.35% (P2C – 10th day). In the group of vacuum-packed sausages, there was a slight decrease in fat content depending on time from 19.89 to 19.56%. In the group of sausages packed only in artificial casings, on the contrary, there was a significant rise in fat content from 19.65 to 25.35%.

The results of the experiment confirmed that the addition of cricket meal slightly increased the protein content ($P \leq 0.05$) in the experimental groups compared to the control, both in samples without and respectively with vacuum.

Belitz et al. (2009) found protein content in selected type of sausages in average 12%, while Quasem et al. (2009) found protein content of 21.1 – 14.8%. Nurul et. al. (2010) also found lower protein content of 10.63 - 16.43%, what is lower compared with results obtained by study of Kodra et al. (2019), who found protein content in sausages ranging from 20.07 to 21.93%.

Our results of protein conten in enriched sausages are compatible with Kodra et al. (2019) who evaluated of total protein in processed meat (sausages) of Tirana markets.

4.1.3 Fat content

Table 5 shows the detected average values of the fat content in the samples. The fat content in the samples ranged from 9.95 (P2V – 14th day) to 16.90% (KC – 10th day and P1C – 10th day). Table 5 shows that the highest fat content was achieved for the samples of the experiment P1C and the control sample KC on day 10. The table also shows that the fat content was overall higher in the group of fresh sausages than in the group of vacuum-packed sausages. Wilcoxon test at the level of significance ($P > 0.05$) did not confirm a significant difference between the measured values of fat content in the monitored period.

Table 6: Average fat content in sausage samples in %

Sample	Day	Average ± *S.D.*
KC	1	15.95 ± 0.41
	4	14.40 ± 0.43

 DOI: https://doi.org/10.15414/2022.9788055225661

	7	15.95 ± 0.42
	10	16.90 ± 0.41
P1C	1	11.50 ± 0.41
	4	15.90 ± 0.42
	7	14.95 ± 0.41
	10	16.90 ± 0.52
P2C	1	12.40 ± 0.41
	4	13.55 ± 0.43
	7	14.90 ± 0.42
	10	15.40 ± 0.44
KV	1	11.90 ± 0.40
	7	12.40 ± 0.42
	14	13.45 ± 0.46
P1V	1	12.95 ± 0.41
	7	11.05 ± 0.40
	14	12.55 ± 0.42
P2V	1	11.90 ± 0.41
	7	11.90 ± 0.43
	14	9.95 ± 0.39

Notes: KC – control group packed in artificial casings with 0% addition of cricket flour, P1C – experimental group packed in artificial casings with 2% addition of cricket flour, P2C – experimental group packed in artificial casings with 4% addition of cricket flour, KV – vacuum-packed control group with 0% addition of cricket flours, P1V – experimental group vacuum packed with 2% addition of cricket flour, P2V – experimental group packaged vacuum with 4% addition of cricket flour

The average values of fat content found in the group of control samples (KV, KC) ranged from 11.90 (KV – 1st day) to 16.90 mass. % (KC – 10th day). In case of samples packed only in artificial casings higher fat content with rising tendency as a function of time, compared to the group of vacuum-packed sausages was found. In the group of vacuum-packed sausages, the highest value of fat content 13.5 wt.% on the 14th day after production was found.

Average values varied in the samples of the experiment (P1V, P1C) in the range from 11.05 (P1V – 7th day) to 16.90% (P1C – 10th day). In the group of sausages packaged only in artificial casings, there was an increase in fat content depending on time. On the 1st day after

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production, the average fat content was found to be 11.9%, while on the 10th day it was found value up to 16.90% fat. In the case of vacuum-packed sausages, it happened to a slight decrease in fat content (on the 7th and 14th day from production) compared to the 1st day from production, where the average fat content was found to be 13%.

The average fat content in the experimental samples (P2V, P2C) varied in the range from 9.95 (P2V – 14th day) to 15.40% (P2C – 10th day). In the vacuum group of wrapped sausages, the fat content decreased depending on time from 11.90 to 9.95%. In the group of sausages packed only in artificial casings, on the contrary, the content increased of fat from 12.40 to 15.40%.

We can also see an upward trend in the group of fresh sausages fat content in both experimental and control samples. On the contrary, at in samples P1V and P2V, the fat content decreased slightly depending on time. The lowest fat content was detected in the P2V sample on the 14th day after production, where the observed sample contained only 9.95% fat.

We can see a smaller fluctuation in the group of vacuum-packed sausages values of fat content compared to the group of fresh sausages. At the same time in this group lower values of fat content were measured.

Yun-Sang et al. (2017) investigated the effect of adding worms Tenebrio molitor to sausages in different additions from 5-30% and found that the fat content decreased with increasing concentrations of Tenebrio molitor meal.

Hyun-Wook et al. (2016) evaluated the impact of the addition of pupae in their research silk threads (*Bombyx mori*) into emulsion salami. The content of fat in thus modified samples ranged from 18.16 to 19.85 wt.%.

4.1.4 Cholesterol content

Table 7 shows the detected average values of cholesterol content in the samples. The cholesterol content in the samples ranged from 1.02% (P2V – 1st day) to 1.36% (P1C – 10th day). The highest cholesterol and fat content was reached in the samples of the experiment P1C and the control sample KC on the 10th day, respectively 7th day. The table also shows that the total cholesterol content was higher in the group of unpackaged sausages than in the group of vacuum-packed sausages.

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Table 7: Protein content in the sausages samples (%)

Sample	Day	Average ± *S.D.*
KC	1	1.21 ± 0.03
	4	1.11 ± 0.07
	7	1.35 ± 0.04
	10	1.31 ± 0.04
P1C	1	1.15 ± 0.03
	4	1.14 ± 0.05
	7	1.10 ± 0.02
	10	1.36 ± 0.06
P2C	1	1.18 ± 0.02
	4	1.04 ± 0.03
	7	1.21 ± 0.07
	10	1.21 ± 0.04
KV	1	1.23 ± 0.02
	7	1.14 ± 0.06
	14	1.24 ± 0.05
P1V	1	1.15 ± 0.02
	7	1.11 ± 0.04
	14	1.13 ± 0.03
P2V	1	1.02 ± 0.02
	7	1.10 ± 0.02
	14	1.12 ± 0.02

Notes: KC – control group packed in artificial casings with 0% addition of cricket flour, P1C – experimental group packed in artificial casings with 2% addition of cricket flour, P2C – experimental group packed in artificial casings with 4% addition of cricket flour, KV – vacuum-packed control group with 0% addition of cricket flours, P1V – experimental group vacuum packed with 2% addition of cricket flour, P2V – experimental group packaged vacuum with 4% addition of cricket flour.

In the group of sausages packed only in an artificial casing, we can see a rising tendency of the cholesterol content in both the experimental samples and the control samples. This tendency is like the solid components of dry matter caused by its higher increase compared to vacuum-packed sausages. The lowest cholesterol value was observed in the P2C group on

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the 4th day (1.04%) and the highest in the P1C group on the 10th day after the production of sausages (1.36%).

On the contrary, in the group of vacuum-packed sausages, we can see smaller fluctuations in cholesterol content values compared to the group of fresh sausages - e.g. in the P1V group it slightly decreased and in the P2V group its content decreased slightly depending on time. At the same time, lower values of fat content were measured in this group - the lowest fat content was found in the P2V sample on the 14th day after production, where the observed sample contained only 1.02% cholesterol.

The average values of the cholesterol content found in the group of control samples (KV, KC) ranged from 1.11 to 1.35% (KC – 7th and 10th day from production, respectively). In the case of samples packed only in artificial casings, higher cholesterol content was demonstrated with an increasing tendency depending on time compared to the group of vacuum-packed sausages. In the group of vacuum-packed sausages, the highest content value of 1.24% was found on the 14th day after production.

In the samples of the experiment (P1V, P1C), the average values ranged from 1.10 to 1.36% (P1C – 7th and 10th day from the production of sausages, respectively). In the group of sausages packed only in artificial casings, there was an increase in the cholesterol content depending on time, like the other investigated parameters. On the 1st day after production, an average cholesterol content of 1.15% was detected, while on the 10th day, a value of up to 1.36% cholesterol was detected. In the case of vacuum-packed sausages, the cholesterol content did not change markedly.

The average cholesterol content in the experimental samples (P2V, P2C) ranged from 1.02 (P2V – 1st day) to 1.21% (P2C – 7th and 10th day). In the group of vacuum-packed sausages, there was an increase in cholesterol content depending on time from 1.02 to 1.12%. In the group of sausages wrapped only in artificial casings, the cholesterol content also increased from 1.18 to 1.21%.

Cholesterol content was slightly reduced ($P \geq 0.05$) in experimental groups of sausages made with the addition of cricket flour compared to the control group without vacuum, and with vacuum, significant differences ($P \leq 0.05$) were found between the control and experimental groups, respectively also between experimental groups.

In study of Baggio and Bragagnolo (2005), respectively Schmid et al. (2009) was found lower cholesterol content in their produced sausages, ranging from 0.61 to 0.66%, what is lower

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compared with our sausages enriched with cricket flour, as we found cholesterol content 1.02 – 1.23% in artificial casings and vacuum-packed sausages, respectively.

4.1.5 pH

Table 8 shows the average pH values in the samples.

Table 8: Average pH value in sausage samples

Sample	Day	Average ± *S.D.*
KC	1	6.60 ± 0.01
	4	6.58 ± 0.01
	7	6.56 ± 0.02
	10	6.49 ± 0.02
P1C	1	6.56 ± 0.09
	4	6.58 ± 0.01
	7	6.58 ± 0.02
	10	6.52 ± 0.02
P2C	1	6.59 ± 0.01
	4	6.56 ± 0.03
	7	6.54 ± 0.02
	10	6.51 ± 0.01
KV	1	6.56 ± 0.01
	7	6.60 ± 0.02
	14	6.53 ± 0.01
P1V	1	6.57 ± 0.02
	7	6.57 ± 0.01
	14	6.52 ± 0.02
P2V	1	6.56 ± 0.01
	7	6.59 ± 0.02
	14	6.52 ± 0.02

Notes: KC – control group packed in artificial casings with 0% addition of cricket flour, P1C – experimental group packed in artificial casings with 2% addition of cricket flour, P2C – experimental group packed in artificial casings with 4% addition of cricket flour, KV – vacuum-packed control group with 0% addition of cricket flours, P1V –

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experimental group vacuum packed with 2% addition of cricket flour, P2V – experimental group packaged vacuum with 4% addition of cricket flour.

Table 8 shows that the pH values did not show significant deviations between individual groups. However, a decreasing tendency of pH values was demonstrated depending on time and also a more significant decrease in values in the group of non-vacuum-packed sausages. In the control samples (KV, KC) the average pH values were within the range from 6.49 (KC – 10th day) to 6.60 (KC – 1st day). In the group of non-vacuum-packed sausages, a decreasing tendency of pH values depending on time was found. In the vacuum group packaged sausages showed a slight increase on day 7 (pH value 6.59) compared to 1st day after production, where the average pH value was found to be 6.56. Then the value again it dropped to a pH value of 6.52 on the 14th day after production.

In the case of experimental samples with 2% addition of cricket flour (P1V, P1C), average pH values ranged from 6.52 (P1V – 14th day and P1C – 10th day) to 6.57 (P1V – 7th day).

Experimental samples with 4% addition of cricket flour (P2V, P2C) were average pH values in the range from 6.51 (P2C – 10th day) to 6.59 (P2V – 7th day).

In both groups a decreasing tendency of pH values was shown depending on time. A decreasing tendency of pH values was demonstrated in the group of fresh sausages. The lowest values were measured on the 10th day after production, while the value dropped more significantly in the case of the control sample (pH value 6.49). They showed up on the 1st and 10th day after production more pronounced deviations of pH values between control and experimental samples. Between samples of the experiment, the deviations from each other were smaller.

In the group of vacuum-packed sausages, no significant deviations were demonstrated in the pH value during the observed period between individual samples. The pH ranged from 6.52 to 6.60 on the 7th day after production, the pH values were the same for all samples (experiment and control). On the 14th day, we observed a decrease in pH values, however compared to the group of fresh sausages, the values of the samples differed only minimally.

Hyun-Wook et al. (2017) investigated the effect of *Acheta domesticus* flour on properties meat emulsion. The authors state that the replacement of lean meat or fat *Acheta domesticus* flour did not significantly change the pH value. The value fluctuated in the range of 6.06 to 6.12. These values are not quite different from the values found by us.

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Yoo-Sun et al. (2017) state in their work that silkworm pupae (*Bombyx mori*) can increase the resulting pH of the meat piece, which indicates that the addition insects can directly affect the pH value of the meat emulsion. The pH values in as follows modified meat part reached a value of 6.39. At the same time, the authors add that the influence of insects to the pH value is individual depending on individual insect species. This is also supported by Yun-Sang et al. (2017) who investigated the effect of flour addition from *Tenebrio molitor* worms into sausages in various additions. The pH values in this case ranged from 5.98 to 6.31.

Table 9: Statistical evaluation of the evidence of differences in the pH value in the group of fresh sausages

	$KČ_1$	$KČ_4$	$KČ_7$	$KČ_{10}$	$P1Č_1$	$P1Č_4$	$P1Č_7$	$P1Č_{10}$	$P2Č_1$	$P2Č_4$	$P2Č_7$	$P2Č_{10}$
$KČ_1$		+	-	+	+	-	-	-	-	-	-	-
$KČ_4$			-	+	-	-	-	-	-	-	-	-
$KČ_7$				+	-	-	-	-	-	-	-	-
$KČ_{10}$					-	-	-	+	-	-	-	+
$P1Č_1$						-	-	-	-	-	-	-
$P1Č_4$							-	+	-	-	-	-
$P1Č_7$								+	-	-	-	-
$P1Č_{10}$									-	-	-	-
$P2Č_1$										-	+	+
$P2Č_4$											-	+
$P2Č_7$												+
$P2Č_{10}$												

 DOI: https://doi.org/10.15414/2022.9788055225661

Table 10: Statistical evaluation of the evidence of differences in the pH value in the group of fresh sausages

	KV_1	KV_7	KV_{14}	$P1V_1$	$P1V_7$	$P1V_{14}$	$P2V_1$	$P2V_7$	$P2V_{14}$
KV_1		+	+	+	-	-	-	-	-
KV_7			+	-	-	-	-	-	-
KV_{14}				-	-	-	-	-	-
$P1V_1$					-	-	-	-	-
$P1V_7$						+	-	-	-
$P1V_{14}$							-	-	-
$P2V_1$								-	-
$P2V_7$									+
$P2V_{14}$									

Differences in pH values were detected between the monitored groups, which are also confirmed by results of statistical analysis. Statistical differences in pH values based on Wilcoxon test at the level of significance ($P<0.05$) were demonstrated in most samples.

At the same time, when comparing individual groups with each other, a difference was demonstrated level of significance ($P<0.05$) between control samples KV – KC (1^{st} day) and samples of the experiment P1V – P1C (1^{st} day), P2V – P2C (7^{th} day).

4.1.6 Water content

Table 11 shows the average values of water content in the samples.

Table 11 shows that the water content in the samples ranged from 39.85 (P1C – 10^{th} day) to 68.65% (P2V – 1^{st} day), which points to great variability. Statistical differences in water content based on the Wilcoxon test at the level of significance ($P>0.05$) they were not proven.

In the control samples (KV, KC) the average values of the water content varied in the range of 43.76% (KC – 10^{th} day) to 68.30% (KV – 1^{st} day).

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In the samples of the experiment with 2% addition of cricket flour (P1V, P1C), the average the water content values ranged from 39.85 (P1C – 10th day) to 68.20% (P1V – 1st day).

Experimental samples with the addition of 4% cricket flour (P2V, P2C) had an average water content ranging from 52.45 (P2C – 10th day) to 68.65% (P2V – 1st day).

A decreasing tendency of the water content as a function of time was demonstrated, while the most significant decrease was recorded in the group of non-vacuum-packed samples. In a group of vacuum-packed sausages, there were significantly smaller losses of water content depending on time.

Table 11: Average water content in sausage samples

Sample	Day	Average ± *S.D.*
KC	1	64.05 ± 0.12
	4	60.17 ± 0.13
	7	52.40 ± 0.09
	10	43.76 ± 0.08
P1C	1	66.80 ± 0.09
	4	61.90 ± 0.12
	7	55.30 ± 0.10
	10	39.85 ± 0.08
P2C	1	66.90 ± 0.12
	4	63.17 ± 0.09
	7	55.13 ± 0.13
	10	52.45 ± 0.10
KV	1	68.30 ± 0.03
	7	67.47 ± 0.09
	14	66.80 ± 0.13
P1V	1	68.20 ± 0.10
	7	67.26 ± 0.12
	14	67.90 ± 0.08
P2V	1	68.65 ± 0.09
	7	68.13 ± 0.05

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	14	68.43 ± 0.04

Notes: KC – control group packed in artificial casings with 0% addition of cricket flour, P1C – experimental group packed in artificial casings with 2% addition of cricket flour, P2C – experimental group packed in artificial casings with 4% addition of cricket flour, KV – vacuum-packed control group with 0% addition of cricket flours, P1V – experimental group vacuum packed with 2% addition of cricket flour, P2V – experimental group packaged vacuum with 4% addition of cricket flour.

In the group of fresh sausages (not vacuum packed), the average water content ranged from 39.85 (P1C – 10th day) to 66.90% (P2C – 1st day). Sample P1C at the same time, it contained the lowest water content within both monitored groups. Table 7 shows that the water content in the analyzed samples decreased significantly ($P \leq 0.05$) depending on time.

Hyun-Wook et al. (2017) investigated the effect of *Acheta domesticus* flour on properties meat emulsion, while they used different additions of this flour (5-30%). The water content ranged from 61.3 – 62.6%, which is not very different from the values we found of water content in the group of non-vacuum-packed sausages.

In the group of vacuum-packed sausages, the water content ranged from 66.80 (KV – 14th day) to 68.65% (P2V – 1st day). Table 7 shows that there were no significant losses of water content in contrast to the samples that were not vacuum packed.

4.1.7 Color of sausages

Table 8 shows the average values for L*, a*, b* in the samples. The lightness values (L*) in the sausage samples ranged from 54.74 (P1C – 10th day) to 62.73 (KV – 14th day). The values of the spectrum (a*) ranged from 13.54 (P2V – 1st day) to 17.42 (P1C – 10th day). More pronounced deviations in the values for showed in the group of non-vacuum-packaged sausages. The values of the spectrum (b*) ranged from 17.39 (P2C – 1st day) to 19.71 (KC – 10th day). Even in this case, there are significant deviations showed in the group of non-vacuum-packaged sausages.

Hyun-Wook et al. (2016) investigated the effect of the addition of common blueberry (Tenebrio molitor) and silkworm pupa (Bombyx mori) in emulsion salami. Lightness values L* ranged from 62.50 to 74.74. Measured values of red color intensity a* were from 5.84 – 6.76. Yellow color intensity values b* from 9.68 – 18.65.

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Table 12: Average color in sausage samples

Sample	Day	L*	a*	b*
KC	1	65.29	14.37	18.01
	4	66.22	14.71	18.35
	7	60.95	16.20	19.16
	10	57.73	17.37	19.71
P1C	1	66.13	14.05	18.27
	4	63.96	14.92	18.08
	7	65.22	14.40	17.72
	10	64.74	17.42	19.16
P2C	1	65.76	13.90	17.39
	4	64.81	14.04	17.99
	7	61.55	15.39	18.73
	10	57.57	16.42	18.97
KV	1	67.24	14.16	17.60
	7	67.01	14.07	17.72
	14	62.73	15.92	18.60
P1V	1	66.40	14.46	17.65
	7	65.90	14.60	17.90
	14	66.60	14.50	17.69
P2V	1	66.59	13.54	17.43
	7	66.02	13.88	17.69
	14	61.85	15.45	18.31

Notes: KC – control group packed in artificial casings with 0% addition of cricket flour, P1C – experimental group packed in artificial casings with 2% addition of cricket flour, P2C – experimental group packed in artificial casings with 4% addition of cricket flour, KV – vacuum-packed control group with 0% addition of cricket flours, P1V – experimental group vacuum packed with 2% addition of cricket flour, P2V – experimental group packaged vacuum with 4% addition of cricket flour.

In the control samples (KV, KC) the average brightness values (L*) varied in the range from 57.73 (KC – 10th day) to 67.24 (KV – 1st day). Larger differences were observed in the group of fresh sausages, where there was a more significant decrease in the value of L* compared to a group of vacuum-packed sausages. Wilcoxon test showed significant differences

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(P≤0.05) between KC and KV samples on the 7th day, KV (1st day) and KV (7th day), KV (1st day) and KV (14th day), KC (1st day) and KC (10th day), KC (4th day) and KC (10th day), KC (7th day) and KC (10th day).

The intensity of the red color (a*) ranged from 14.07 (KV – 7th day) to 17.37 (KC – 10th day). The intensity of the yellow color (b*) ranged from 17.60 (KV – 1st day) to 19.71 (KC – 10th day).

In the experimental group (P1V, P1C) with 2% addition of cricket flour, the average values for brightness (L*) ranged from 54.74 (P1C – 10th day) to 66.60 (P1V – 14th day). More pronounced deviations in the brightness value were seen in the non-vacuum-packed group sausages with a decreasing tendency of values. There were deviations for vacuum-packed sausages at least.

The intensity of the red color (a*) ranged from 14.05 (P1C – 1st day) to 17.44 (P1C – 10th day). Wilcoxon test showed differences (P≤0.05) between samples P1C (1st day) and P1C (10th day), P1C (4th day) and P1C (10th day), P1C (7th day) and P1C (10th day). The intensity of yellow color b* varied in the range from 17.65 (P1V – 1st day) to 19.16 (P1C – 10th day). Wilcoxon test showed significant differences (P≤0.05) between samples P1C (1st day) and P2C (1st day).

In the group with 4% addition of cricket flour (P2V, P2C), the brightness value L* again showed more significant differences in the group of non-vacuum-packed sausages. Average values ranged from 57.57 (P2C – 10th day) to 66.59 (P2V – 1st day). Wilcoxon test showed significant differences (P≤0.05) between P2C samples (1st day) and P2C (7th day), P2C (1st day) and P2C (10th day).

The values of the a* ranged from 13.54 (P2V – 1st day) to 16.42 (P2C – 10th day). In both groups, an increasing tendency of values was noted, however it was more pronounced in the group of non-vacuum-packed samples. The b* spectrum values varied in the range from 17.39 (P2C – 1st day) to 18.97 (P2C – 10th day).

Yoo-Sun et al. (2017) in their research evaluated the effect of yarn addition (*Bombyx mori*) on the physico-chemical properties of minced meat. Brightness values L* ranged from 55.57 – 62.31; values of a* 6.69 – 8.35 and b* 18.68 – 22.45.

Sousa et al. (2017) analyzed the addition of hydrolyzed collagen to sausages. The values of brightness L* were in the range from 61.22 to 64.61. The intensity of red color a* was in samples from 13.83 – 15.01, while the control sample without the addition of hydrolyzed collagen showed lower values. In the case of the intensity of the yellow color b*, the values

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ranged from 11.42 to 12.21. These values increased with increasing addition collagen into products.

The average values of brightness L* in the group of fresh sausages showed downward trend. The highest brightness (L*) was found in the KC sample (4th day) with a value of 66.22. On the contrary, the lowest value was in sample P1C (10th day) with a value of 64.74, and thus this the sample was darkest.

Pipek et al. (1998) informs about the color mainly the brightness value L*. That is a given content of hem dyes (myoglobin and hemoglobin), but also pH value or hydration the state of the raw material.

In the group of vacuum-packed sausages (Fig. 16), the average brightness values L* ranged from 61.85 (P2V – 14th day) to 67.24 (KV – 1st day). Unlike of the group of non-vacuum-packed sausages, there was no significant decrease in the case of sample P1V, on the contrary, the values were almost stable.

Sample P1V can be considered the lightest, on the contrary, the darkest sample was P2V (14th day) with a brightness value of 61.85. From a significant decrease in values for all samples it happened on the 7th day from production.

The intensity of the red color (a*) was in the group of non-vacuum-packed sausages on the 1st day almost the same. The highest intensity was achieved by samples P1C – 10th day (17.42) and KC sample – 10th day (17.37). On the contrary, the lowest intensity of red color (13.90) proved the sample P2C – 1st day.

According to Sang-Keun et al. (2018) there is a darkening of the color of meat products due to lipid oxidation. This process can be triggered by the autoxidation of unsaturated of fatty acids by atmospheric oxygen.

This idea is also supported by Suchý et al. (2017), according to which it was demonstrated that that oils extracted from insects are rich in polyunsaturated fatty acids. The authors themselves believe that the presence of unsaturated fatty acids leads during processing insects to quick oxidation with subsequent swallowing.

In the group of vacuum-packed sausages, the P2V sample had the lowest value of a* (1st day) – 13.54. The highest intensity of red color was achieved by the KV sample (14th day) – 15.92. Again, an increasing trend over time was demonstrated. Less prominent increase in the intensity of the red color was demonstrated by the P1V sample, which throughout of the observed period had almost balanced average values of the intensity of the red color.

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The average values of b* varied in the group of non-vacuum-packed sausages in the range from 17.39 (P2C – 1st day) to 19.71 (KC – 10th day). In the case of KC and P2C samples, it occurred to the gradual increase in the intensity of the yellow color over time. An exception was sample P1C where there was a decrease in intensity up to the 7th day after production and then a subsequent increase.

Numerical average values of the b* spectrum in the group of vacuum-packed sausages ranged from 17.43 (P2V – 1st day) to 18.60 (KV – 14th day). KV and P2V samples had almost the same values and showed an increasing tendency of the b* value. On the contrary, the sample P1V showed the same as in the case of the brightness values (L*) and intensity of red color (a*) in the group of vacuum-packed sausages an almost constant tendency of values depending on time.

4.2 Sensory analysis of sausages

We subjected the produced sausage samples to a sensory analysis on the 7th day after production. The results of the sensory evaluation show that the evaluators accepted the samples positively. The lowest awarded value was 3, the highest 6. From the individual point evaluations then he worked out the average for each monitored parameter. From the obtained results, prepared graphs, focusing on the comparison of fresh and vacuum groups wrapped sausages to each other, but also a comparison of control samples (KC = control sample for fresh sausages, KV = control sample for vacuum-packed sausages) and experimental samples (P1 = 2% addition of cricket flour, P2= 4% addition of cricket flour) between themselves.

Overall evaluation of the sensory profile for individual groups of sausages (fresh, vacuum packed) describe Fig. 7 and Fig. 8.

For the group of fresh sausages, there were not found significant point deviations between the control (K) and the experimental groups (P1, P2). When evaluating the smell, the sample was rated best P1C, which received the highest average point rating of 5.9. In this case, the evaluators rated the aroma as harmonious, typical of the sausage and the spices used. At in the evaluation of taste, the P1C sample was again the best with an average of 5.9 points. The worst P2C sample turned out with an average of 5.3 points. It is generally known that fat is the carrier of taste. It is therefore possible that the high score obtained with this parameter

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can also related to the higher representation of fat found in the group of fresh sausages compared to a group of vacuum-packed sausages.

In terms of juiciness, the best rated samples were P1C and P2C, which received the same average number of points 5.1. The control sample received 4.7 points. On the contrary, in the assessment in terms of softness and tenderness, the control sample with an average of 5.1 points was the best. The color was the best rated in possibly the control sample and P2C sample with an average of 5.1 points.

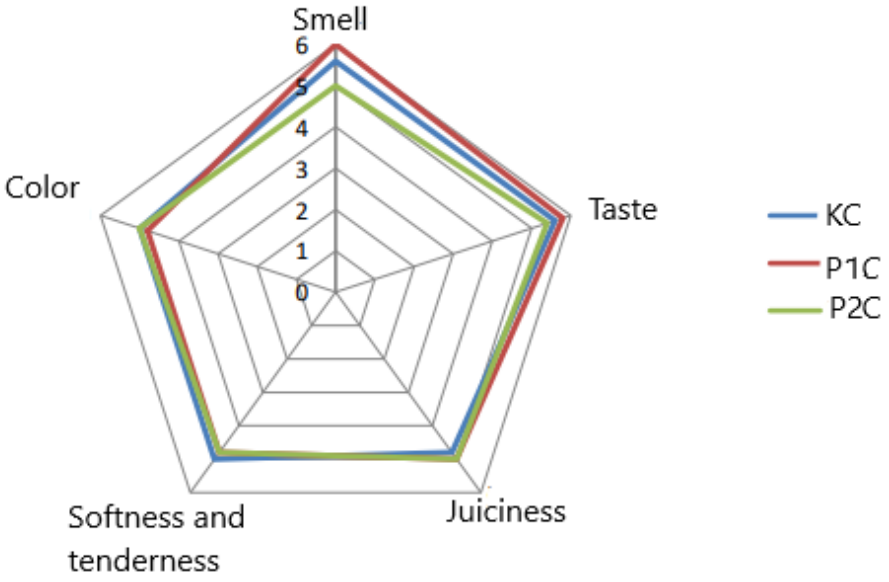

Figure 7: Sensory evaluation results for the group of fresh sausages (day 7)

In the group of vacuum-packed sausages (Fig. 8), it was different from fresh sausages the best-rated parameter is softness and tenderness. It was the best of this group evaluated control sample with an average of 5.9 points. When evaluating the aroma and taste, the best was P2V sample with an average of 5.3, and vice versa, the control sample with the worst score of an average 4.7. Juiciness was best evaluated in the case of the control sample and P1V samples. When judging the color, the P1V sample was the best with 4.5 points and the worst control sample with 3.7 points. It was for this parameter that the lowest points were awarded within all groups.

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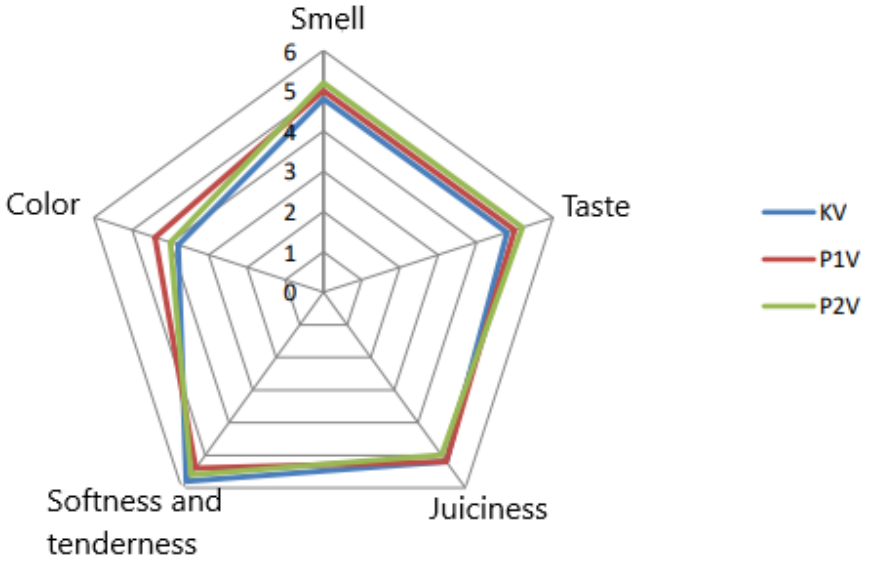

Figure 8: Sensory evaluation results for vacuum-packed sausages (day 7)

When comparing the control samples with each other, differences were found within the individual samples evaluated parameters (Fig. 9). The biggest differences were found in color. In the case of KV an average value of only 3.7 points was obtained. In terms of color, it was for the evaluators more acceptable sample of KC, which received up to 5.1 points. These samples were darker than the vacuum ones packaged sausages, but they were more attractive to the evaluators.

According to Sang-Keun et al. (2018) are generally sensory properties such as color, texture, aroma and taste affected by lipid oxidation in meat products.

Suchý et al. (2017) state that the presence of unsaturated fatty acids during the processing of insects for food leads to rapid oxidation causing swallowing.

When evaluating the aroma and taste, the KC samples turned out better. Tenderness and softness was however better in the case of the KV sample. This may be related to evaporation water from the surface of sausages that were not vacuum packed, which increased the dry matter and the samples were stiffer and drier compared to KV samples.

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Figure 9: The results of sensory evaluation between control samples KV, KC

When evaluating the samples with 2% addition of cricket flour, it was found to be more significant in monitored smell and taste descriptors. When judging the smell, it turned out well preferably the sample P1C, which was evaluated with the highest number of points in the case of all evaluators and thus 6 points. P1V samples received 4.9 points.

Taste is an important factor for the acceptance of a new food product. Sample P1C received a very high score of 5.8 points, while the P1V sample received 5 points. In the case of the other monitored parameters, there were no significant deviations between the samples.

When evaluating the color, the P1V sample turned out to be the worst. It could have been caused with a high brightness value L* (66.60) compared to other samples. This sample was the brightest, which could have led to a low score from the evaluators.

Caparroso Megido et al. (2016) observed the acceptability of hamburgers based on insects among consumers in Western countries. The evaluators were given 3 unmarked samples of meat, insect and vegetable burgers. They were evaluated most positively meat hamburgers; insect hamburgers took second place. From the study it follows that insect-based hamburgers were more acceptable to consumers than their vegetable versions. The authors believe that it is related to the ability of insects at least to partially retain the sensory properties of the meat.

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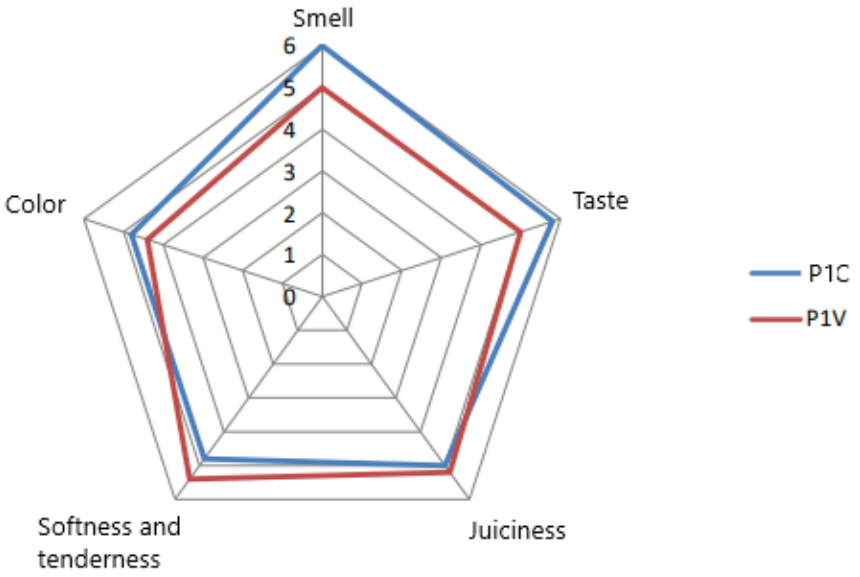

Figure 10: Results of sensory evaluation between samples P1C, P1V

When evaluating the samples with 4% addition of cricket flour, there were significant deviations only for the monitored parameters, color, softness and fragility. When evaluating the color, P2C turned out better with an average of 5 points. The P2V sample was rated only 3.9 points. The point difference between the P2C and P2V samples may again be related to the brightness value L*. In the case of P2C, on the 7^{th} day after production, the measured brightness value L* was 61.54, in the case of P2V up to 66.02. It follows that the sample P2C was darker than the sample P2V, which could be more attractive to evaluators.

In the case of the observed descriptor, delicacy, fragility, the P2V sample turned out better with an average of 5.6 points. The P2C sample received an average rating of 4.8 points. In case other monitored parameters did not show significant deviations.

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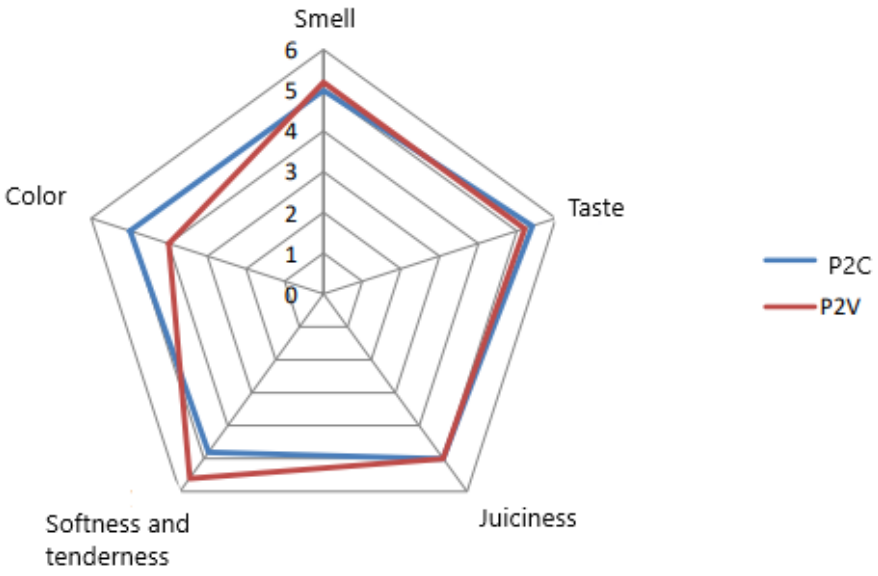

Figure 11: Results of sensory evaluation between P2C, P2V samples

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5 CONCLUSION

The consumption of traditional meat sources is under pressure due to the high impact on the environment.

Entomophagy can be one of the solutions to the globally growing demand for proteins and the incorporation of non-traditional foods that can increase their added value.

The aim of the scientific monograph was to produce a soft meat product (sausages) without and with the addition (2 and 4%) of cricket flour (*Acheta domesticus*). Part of the samples was packed in artificial casings without vacuum and the remaining part was vacuum packed.

When evaluating sausages, we focused on determining the content of fat, cholesterol, protein, NaCl, water, pH, color and representation. At the same time, we subjected the samples to a sensory analysis on the 7th day after production in order to assess possible differences between these products.

The values of the fat content in the sausages ranged from 9.95 to 16.90 wt. %. A more pronounced fluctuation of values was demonstrated in the group of non-vacuum-packed sausages. The addition of cricket flour did not have a significant effect on the fat content of the sausages.

Cholesterol content was slightly reduced ($P \geq 0.05$) in experimental groups of sausages made with the addition of cricket flour compared to the control group without vacuum, and with vacuum, significant differences ($P \leq 0.05$) were found between the control and experimental groups, respectively also between experimental groups.

The results of the experiment confirmed that the addition of cricket meal slightly increased the protein content ($P \leq 0.05$) in the experimental groups compared to the control, both in samples without and respectively with vacuum.

The NaCl content ranged from 1.41 to 2.55%. Deviations were again more pronounced in the case of non-vacuum-packed sausages. In both groups, an increasing tendency of values was observed depending on time.

The pH values had a decreasing tendency from 1 to 10, respectively. 14 days of sausage storage in both observed groups, i.e. without or with vacuum. In the case of vacuum-packed sausages, a significant decrease occurred on the 14th day after production, otherwise the values were almost constant.

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The water content was in the range of 39.85-68.65%. Even in this case, there were demonstrable differences in the values found for non-vacuum-packed sausages, while the water content decreased significantly depending on the storage time.

More pronounced differences in color characteristics were demonstrated by the sample with 2% addition of cricket flour. In general, the group of vacuum-packed sausages showed less color changes during storage.

It is known that vacuum-packed foods stored at low temperatures retain their organoleptic properties because the oxidation process is slowed down and their shelf life is also extended.

Based on the results of the sensory evaluation, we can state that the manufactured product with the addition or without the addition of cricket flour, it was accepted positively by the sensory committee, while the deviations between the observed descriptors were minimal.

The prevailing problem that prevents the spread of entomophagy is clearly neophobia and lack of information on the part of people - consumers. Many researches have confirmed that the higher acceptability of the application of insects is in an invisible form in known food products. Insect flour is often added to various types of bakery products or products for athletes, but very little research has focused on the effect of the addition of insects, or of insect meal on the physico-chemical indicators of meat products, e.g. sausages.

Based on the obtained results, we can conclude that the addition of 2 and 4% of cricket meal did not have a significant effect on the properties of the produced soft meat product, i.e. sausages. More significant changes could be seen with higher additions of this cricket flour, but further research is needed.

We can also state that the vacuum packaging of the products showed significantly smaller changes during storage and therefore we consider it a better option considering the preservation of better organoleptic parameters of the soft meat product, i.e. sausages.

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Abstrakt

Pre mnoho národov či etnických skupín je konzumácia hmyzu neodmysliteľnou súčasťou jedálnička a tiež je aj často základom ich tradičných pokrmov. Vzhľadom na rastúcu populáciu sa dá predpokladať, že bude nutné hľadať ďalšie alternatívne zdroje výživy. Zo súčasných dostupných vedeckých poznatkov vyplýva, že niektoré druhy hmyzu sa považujú za vhodný alternatívny zdroj potravy a hlavne bohatý zdroj bielkovín. Vo vedeckej monografii bolo snahou poukázať na potenciál využitia hmyzu (cvrčej múčky) vzhľadom na rastúci dopyt po potravinách a potrebe trvalo udržateľného alternatívneho zdroja potravín. Pre experiment boli vyrobené párky s 2 % a 4 % prídavkom cvrčej múky spolu s kontrolnými vzorkami bez prídavku tejto múky skladované v čerstvom stave, resp. vo vákuu. Obsah tuku sa pohyboval v rozmedzí od 9.95 to 16.90 hm. %. Obsah biekovín bol zvýšený vo všetkých skupinách s prídavkom cvrčej múčky v množstve 2, resp. 4 % a to aj štatisticky významne ($P \leq 0,05$) oproti kontrolnej skupine. Obsah cholesterolu bol vo všetkých skupinách vyrovnaný a dosiahol hodnoty od 1,02 do 1,36 %. Obsah NaCl bol od 1,41 do 2,55 %, pričom hodnoty mali stúpajúcu tendenciu v závislosti od času skladovania. Hodnoty pH boli vo všetkých skupinách vyrovnané. Obsah vody bol v rozmedzí 39.85-68.65%. Z hľadiska hodnotenia farby boli zaznamenané väčšie rozdiely pri čerstvých párkoch bez vákua ako u párkov skladovaných s vákuom. V rámci senzorického hodnotenia výsledky poukazujú na pozitívne prijatie výrobku, pričom odchýlky pri jednotlivých skupinách experimentu medzi sledovanými deskriptormi neboli výrazné.

Kľúčové slová: hmyz, cvrčia múčka, párky, fyzikálno-chemické vlastnosti, senzorika

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Abstract

For many nations or ethnic groups, the consumption of insects is an integral part of the diet and is also often the basis of their traditional dishes. Due to the growing population, it can be assumed that it will be necessary to look for other alternative sources of nutrition. From the currently available scientific knowledge, it follows that some types of insects are considered a suitable alternative source of food and, above all, a rich source of protein. In the scientific monograph, the effort was to point out the potential of using insects (cricket meal) in view of the growing demand for food and the need for a sustainable alternative source of food. For the experiment, sausages with 2% and 4% addition of cricket meal were made together with control samples without the addition of this flour stored fresh, or in a vacuum. The fat content ranged from 9.95 to 16.90 wt. %. The protein content was increased in all groups with the addition of cricket flour in the amount of 2 or 4%, even statistically significant ($P \leq 0.05$) compared to the control group. The cholesterol content was balanced in all groups and reached values from 1.02 to 1.36%. The NaCl content was from 1.41 to 2.55%, while the values had an increasing tendency depending on time. The pH values were balanced in all groups. The water content was in the range of 39.85-68.65%. In terms of color evaluation, greater differences were noted for fresh sausages without vacuum than for sausages stored with vacuum. As part of the sensory evaluation, the results indicate a positive acceptance of the product, while the deviations in the individual groups of the experiment between the monitored descriptors were not significant.

Key words: insects, cricket meal, sausages, physico-chemical properties, sensorics

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THE EFFECT OF THE ADDITION OF CRICKET FLOUR AS AN ADDED VALUE ON THE QUALITY OF SAUSAGES

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