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Potential and limitations of rabbit meat in maintaining food security in Ukraine

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ABSTRACT

The aim of the present review was to assess whether rabbit meat production can help to improve food security in Ukraine and whether it can make a meaningful contribution to the national economy. Rabbit meat is a nutrient-rich and affordable food with a lower environmental impact than red meat from cattle or sheep. Rabbit meat is considered healthy, as it is lower in fat, cholesterol and sodium than other types of meat, and rich in protein. In addition, rabbit meat proteins can serve as a source of bioactive peptides with the angiotensin converting enzyme (ACE) inhibition properties. The health-promoting properties of rabbit meat and role of associated by-products in providing nutritious and safe food for consumers, and in reducing waste in the meat sector, should be promoted. In Ukraine, rabbit meat products are already recommended as part of a healthy diet for children, pregnant women and the elderly, and the market could be broadened by introducing more rabbit-based products for the whole population. Rabbit production in Ukraine is a promising area of economic activity and with a broader market this segment could increase further and become a significant part of the economy. However, the rabbit farming sector in Ukraine needs comprehensive improvement to address existing issues, including the introduction of sustainable production methods in accordance with European animal welfare and meat quality standards.

1. Introduction

Addressing the problem of hunger and malnourishment is one of the major global challenges. Food security means access to safe food and optimal nutrition, requiring a sustainable food system, and food access is closely related to food supply. When Russian forces invaded Ukraine on 24 February 2022, food security was impaired not only among the Ukrainian people, but also globally. To address the issues that arose, sustainable food production and consumption should be a high priority.

In Ukraine, rabbit meat has a long consumption history. However, only a minor proportion of the rabbit meat consumed (3%) is produced by agricultural enterprises, while the remaining 97% of rabbits in Ukraine are reared by private households. Backyard production of rabbits, mainly for family consumption, is also popular in Ukraine. During the pre-war period, rabbit meat-based products and even live rabbits could be purchased in informal markets in Ukraine (Sõukand, Stryamets, Fontefrancesco, & Pieroni, 2020). In addition to meat, rabbits are produced for fur (Luchyn, 2022). The development of organic rabbit meat farming is suggested to be of particular economic importance for the Ukrainian industry compared with production of other animals (Kotelevych, 2019). Indeed, before the war, organic rabbit farming was considered as an element of sustainable development of regions/households and as an alternative to industrial rabbit farming. Such producers use their own feed resources and do not include higher labour costs in the price. The price of organic rabbit meat depended on supply and demands and was in fact higher than that of industrial rabbit meat. The extent to which such rabbit farming meets the requirements of organic production needs to be studied. In the post-war period, considering the higher price of organic rabbit meat, consumption of organic meat will likely decrease. Rabbit production has been identified

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as the most promising industry for the future supply of functional meat products and fur raw materials (Kotsyubenko, 2012). The rapid body weight growth, high reproduction rate and good feed efficiency of rabbits, and the profitability of rabbit farming, mean that this production enterprise can be attractive to farmers.

Ukraine is now facing vulnerability in food supply arising from the ongoing military conflict, with food shortages affecting individuals and the general population. In particular, structural weaknesses in food production systems have led to a reduction in meat consumption in Ukraine. Rabbit meat has a number of beneficial properties compared with other types of meat, such as higher content of polyunsaturated fatty acids (PUFA) and lower fat content (Cullere & Dalle Zotte, 2018). These are important characteristics of meat, especially for Ukraine and other countries with high consumption of saturated fat and an associated risk of obesity and hypertension (Nyankovskyy et al., 2014; Rukavchuk, Kozlovska, Simochko, & Boyko, 2022). Moreover, rabbits are relatively simple to rear and have a short gestation period, rapid growth rate and high reproductive potential. They also utilise forage protein more efficiently than other livestock animals. Thus, intensification of rabbit farming for meat production could at least partly address food security issues in Ukraine and elsewhere.

Modern farmers also need to focus on the sustainability of their production system and select alternative feed sources that can increase economic profitability without compromising meat quality and safety. There have been a number of recent reviews on rabbit meat (Cullere & Dalle Zotte, 2018; Ebeid, Tůmová, Al-Homidan, Ketta, & Chodová, 2022; Morshdy, Mohieldeen, El-Abody, Mohamed, & Darwish, 2022; Siddiqui et al., 2023), but these did not evaluate the potential contribution of rabbit meat to sustainable production and consumption in Ukraine. Thus the aim of the present study was to assess whether rabbit meat production can help to improve food security in Ukraine and whether it can make a meaningful contribution to the national economy. We also aimed to predict factors that may contribute to success of the development of the commercial meat rabbit industry in post-war Ukraine. This aim was achieved by collecting, evaluating and analysing data from publications in peer-reviewed scientific journals and conference proceedings written in English, Ukrainian and Russian.

2. Military conflicts and farm animal production

Military conflicts have devastating consequences on agriculture and livestock animals, which are greatly dependent on humans (Chishti, Khalid, & Sana, 2023). During the war, the animals can be killed directly as the result of attacks and violence. Moreover, shortages of feeding, veterinary care and veterinary medicines are common, and the animals become prone to diseases. Animals can also be lost due to mines.

Limited information exists on rabbit production and consumption as a consequence of military conflicts. During the Second World War, the rabbit population in the United States of America increased due to depressed economic growth and limited access to other meats as well as relatively low costs of backyard rabbit production (Lukefahr, Cheeke, Mcnitt, & Patton, 2004). The Second World War resulted in the extensive development of rabbit production also in Europe and Japan (Mbutu, 2013), and in the Soviet Union (Tinaev, 1988).

One of the reasons of rabbit meat popularity during military conflict is rabbit highly efficient feed conversion capacity. According to Lukefahr et al. (2004), rabbit production has lower costs because feeds can be produced on small farms, using rabbit manure as fertilizer in gardens and crop plots, and using the greens or wastes, such as bran from cereal grains and peelings from roots and tubers in the rabbit's diet.

After the war, Ukraine will face new challenges in agricultural production including i) mine clearance of a large number of territories; ii) restoration of damaged infrastructure (elevators, cold storage facilities, ports, railways); iii) restoration of destroyed farms, purchase of stolen or destroyed equipment; iv) staffing of farms and v) finding alternatives or restoring the damaged irrigation system. It will not be possible to quickly eliminate the consequences of the war without outside help. The speed of recovery will depend on the available financial and labour resources.

It is difficult to predict how much Ukraine will produce after the war. According to Ukrainian Club of Agrarian Business (UCAB), direct losses of agriculture until June 2023, were estimated to be 8.7 billions USD (machinery – 4.7 billions; agricultural products – 1.9; warehouses – 1.3; farm animals – 0.3). Additional to the above mentioned loses there are some indirect loses – 31.5 billion USD (disruption of logistic – 14.5; decrease in crop production – 13.8; reduction of crop production – 1.7; increase in production costs – 0.8; decrease of perennial crops production – 0.45 (Oleksandra Avramenko, personal communication). Nevertheless, it is obvious that there will be enough crop production for domestic consumption (including feed).

3. Rabbit meat production worldwide and in Ukraine

3.1. Rabbit production

According to estimated values retrieved from FAOSTAT, world production of rabbit meat in 2021 was approximately 505.5 tonnes (FAOSTAT, 2023). China remains the global leader in rabbit production, followed by North Korea and Egypt (Table 1). The top 10 rabbit-producing countries also include Spain, France, Italy, Algeria, Sierra Leone, Russian Federation and

Ukraine (contributing 1.1–3.4% of the total). Ukraine is ranked 8th in global rabbit production, contributing 1.1% of the total volume produced. Around 12.0 thousand tonnes of rabbit meat (slaughter mass) were produced in Ukraine in 2018, which corresponded to 0.5% of total domestic meat production from livestock animals and poultry (Kovalenko, Verbytskyi, Yashchenko, & Lysenko, 2020). In 2021, 21.4 thousand tonnes of rabbit meat (live weight) were produced (Table 2). The total number of rabbits on all categories of farm holding in Ukraine in January 2022 was 4.37 million head (Animal Production in Ukraine, 2021, 2022). The largest numbers of rabbits are produced in northern and western regions of the country (Kyiv, Zhytomyr, Vinnytsia, Lviv and Odesa oblasts), accounting for 45.1% (Fig. 1). The lowest numbers are produced in Rivne, Zakarpattia, Kherson, Luhansk and Zaporizhzhia regions, accounting for only 4.8%. The latter regions have seen a strong decline in the number of rabbits over the past five years.

Private households rear the majority (97.1%) of rabbits in Ukraine, with agricultural enterprises rearing the remaining 2.9% (Prokopenka, 2022). Industrial rabbit farms in Ukraine are vertically integrated enterprises with a closed production system, which includes the whole cycle from insemination to selling the meat. In contrast, rabbit production in other countries is specialised and involves the use of insemination centres (such as Eurolap) and slaughterhouses, which buy live rabbits from farmers and deliver meat to supermarkets and butchers'

Table 1
World production of rabbit meat in 2021 and the top 10 rabbit-producing countries.*

Rank	Country	Production volume in 2021, thousand tonnes	Share of production, %
1	China	275.337	54.5
2	Democratic People's Republic of Korea	100.895	20.0
3	Egypt	58.000	11.5
4	France	17.305	3.4
5	Algeria	8.474	1.7
6	Sierra Leone	8.142	1.6
7	Russian Federation	7.822	1.5
8	Ukraine	5.660	1.1
9	Mexico	4.496	0.9
10	Peru	2.840	0.6
	World production	505.548	100

* https://www.fao.org/faostat/en/#data/QCL.

Table 2
Types of holdings producing rabbits for slaughter in Ukraine, 1990–2021. Data presented as thousand tonnes of live weight.*

Year	All types of holdings	Agricultural enterprises	Households
1990	60.5	0.7	59.8
2000	27.8	0.0	27.8
2010	27.2	0.5	26.7
2015	26.5	1.9	24.6
2019	23.2	1.1	22.1
2020	22.2	1.6	20.6
2021	21.4	1.2	20.2

* Prokopenka, O., 2022.

shops. By 2021, there were 39 industrial-type agricultural rabbit farms in Ukraine and these accounted for 2.9% of total production of rabbit products (Prokopenka, 2022). Some enterprises, such as "Krolikoff", have purchased technological equipment prescribed for slaughterhouses in the European Union (EU), which allows them to produce not only whole rabbit carcasses, but also separately packaged tongue, liver, heart and carcass parts for sale (Honchar, Boiko, & Havrysh, 2020). Most of these industrial-type rabbit farms are located in the Kyiv, Lviv and Dnipro regions, while eight regions of Ukraine have no industrial rabbit farms at all. This includes the Vinnytsia region, which ranks third in rabbit meat production, but where all rabbits are reared by private households (Prokopenka, 2022).

Recent decades have seen a decline in rabbit production in Ukraine, with both the COVID-19 pandemic and Russian military aggression having a negative impact (Fig. 2). Global rabbit meat production also declined in the period 2015–2020 (Overview of Global Rabbit Meat Market, 2023).

3.2. Rabbit breeding in Ukraine

There are about 200 breeds of rabbits in the world and a large number of different breeds are used in the Ukrainian rabbit industry. These are mainly imported breeds, e.g. 45% of the total number of rabbits are New Zealand White and Californian, which are specialist meat rabbit breeds developed in the United States (Honchar et al., 2020). The remaining 55% of rabbits in Ukraine are a mixture of meat and fur breeds, with a very small number of the specialist fur breed Rex. Only two of these breeds were developed in Ukraine. These are Poltava Silver and Grey Giant, both of the meat and fur type. Breeds of this type are gradually declining in popularity, partly because of the falling price of fur and partly because of low pelt quality since meat rabbits do not have time to complete their seasonal moult. A complete moult takes 145 days and slaughter in broiler rabbit breeding on industrial farms is carried out at 75–80 days and in private households often at 90–100 days, which results in low-quality skins. These can be used for certain products, but they cannot match the products from fur breeds of rabbits that are raised for five months, which cost >300 Ukrainian Hryvnia per unit (Honchar et al., 2020).

To provide rabbit breeders with high-quality and highly productive breeding stock, it is necessary to have breeding farms (breeding producers) for all rabbit breeds used in Ukraine. However, establishment of breeding farms is not possible without government support. Large industrial rabbit farms in Ukraine usually use hybrid rabbit lines (hyplus, hyla) and, to a lower extent, the New Zealand White, Californian, White Pannon and Blanc de Termonde breeds. All these rabbit breeds are produced by private households (Honchar et al., 2020).

Scientific support for rabbit breeding is provided by three scientific institutions within the National Academy of Agrarian Sciences of Ukraine (NAAS of Ukraine): the Cherkasy Research Station of Biological Resources of NAAS of Ukraine, the Institute of Animal Husbandry, and the Carpathian State Agricultural Research Station at the Institute of Agriculture for the Carpathian Region. The main task of these institutions is to find new methods and improve existing methods of rabbit production in industrial and household breeding.

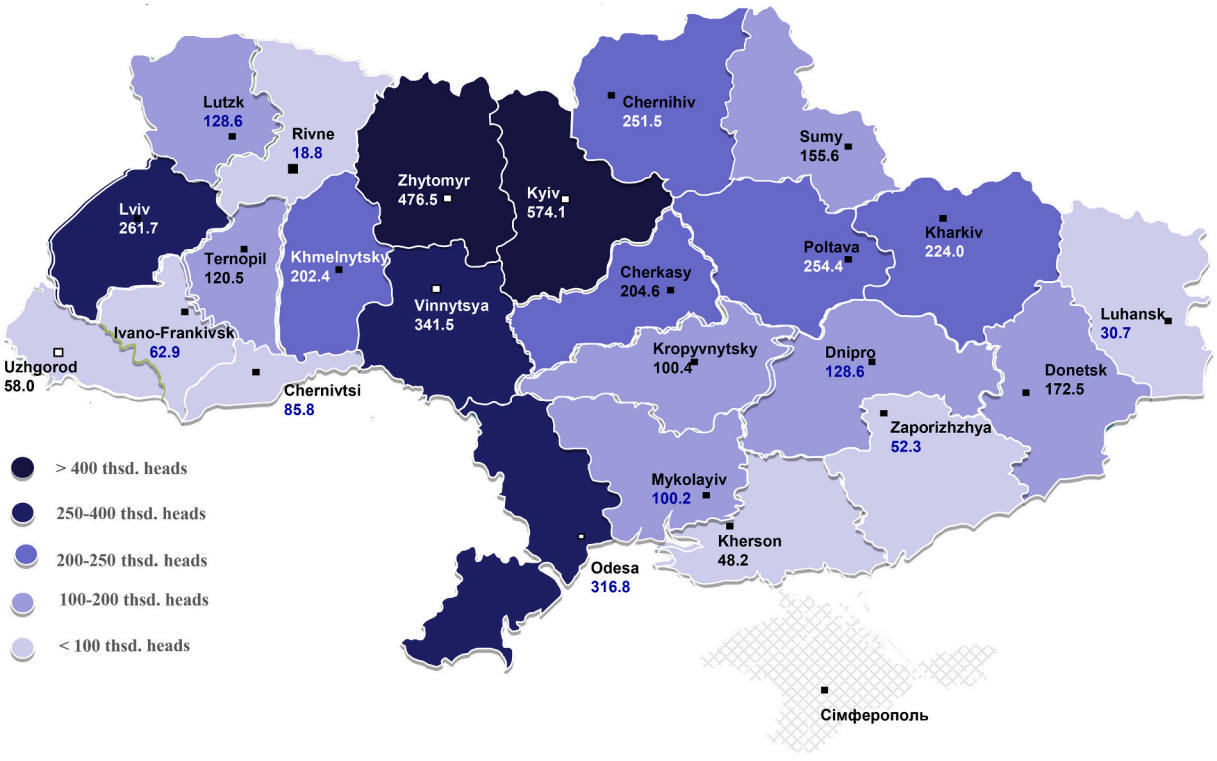

Fig. 1. Number of rabbit heads in different regions of Ukraine in 2022 per 1 January 2022. Data exclude the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol; as of the 1st January 2015–2019 and a part of temporarily occupied territories in the Donetsk and Luhansk regions.

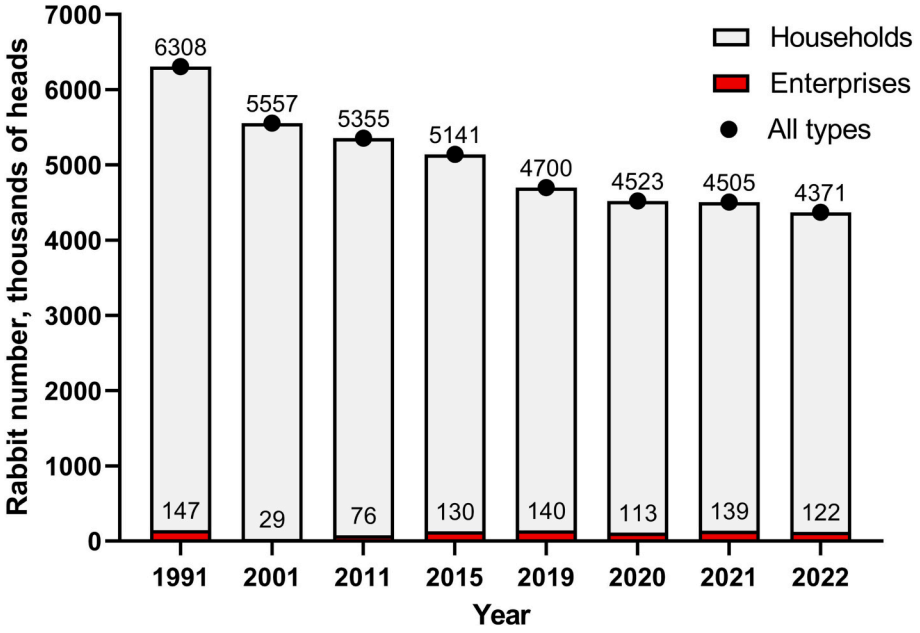

Fig. 2. Number of rabbits kept on different types of agricultural holdings in Ukraine, 1991–2022.

4. Impact of rabbit meat production on environment

The growing global demand for animal protein is having an adverse effect on the environment. Compared with other meat types, rabbit meat can be considered an environmentally friendly food source. Rabbits have a short life cycle, short gestation period (approximately 30 days) and high feed conversion capacity. Partial replacement of conventional meats such as beef and pork with rabbit meat can be an attractive strategy to reduce resource utilisation and greenhouse gas emissions. The average feed conversion ratio of rabbits during the fattening period is estimated to be approximately 3, which is somewhat higher than in broiler chickens (Gidenne, Garreau, Drouilhet, Aubert, & Maertens, 2017). Feed efficiency in rabbit production in relation to environmental aspects was recently reviewed by Gidenne et al. (2017), who identified benefits for the environment of dietary inclusion of rabbit meat. The actual environmental impacts of rabbit production were studied by Cesari et al. (2018), who identified several possibilities to reduce the environmental impacts of rabbit production.

Food losses and food waste are a major problem in the modern food sector (Karwowska, Łaba, & Szczepański, 2021). Reducing waste in the meat sector would make it possible to meet at least some of the challenges to food security in Ukraine and worldwide. Research on the re-utilisation of food waste and by-products has increased in recent decades and, since the Russian invasion, these issues are being addressed with more urgency in Ukraine. Reducing food waste also contributes less to global warming and increases protection of natural resources. The by-products (skin and ears) from rabbit production are a rich source of collagen, which can be used as a food additive or in biomedical and pharmaceutical products (Tang et al., 2022; Toniasso et al., 2022). Rabbit bones can also be used in value-added products, e.g. Ren et al. (2017) obtained a natural calcium supplement from rabbit bones, while Wulandari, Hermiyati, Iswahyuni, and Tawarniate (2022) developed a procedure to prepare rabbit bone gelatin. Rabbit viscera can be processed and used for human consumption (Shaobo Li et al., 2018).

5. Nutritional composition of rabbit meat

Rabbit meat is generally considered to be a healthier alternative to beef and pork. However, the actual nutritional composition of rabbit meat can be affected by intrinsic and extrinsic factors, including genotype, sex, age, husbandry and diet (Gál, Zapletal, Jakešová, & Straková, 2022; Luchyn, 2022).

5.1. Protein, peptides and amino acids

Like other meats, rabbit meat is an excellent source of protein. The protein content is breed-dependent, ranging from 17% to 26% in *Longissimus thoracis et lumborum* (LTL) and hind-leg meat (Kumar, Kim, Jayasena, & Jo, 2023). This is comparable to, or higher than, the protein content in chicken meat (Vlaicu et al., 2022). Protein from rabbits is of high quality and, like other animal proteins, contains all the essential amino acids that the human body cannot make itself. Some studies have indicated that rabbit meat also has a higher content of essential amino acids than other meats (Bivolarski, Vachkova, Ribarski, Uzunova, & Pavlov, 2011; Nasr, Abd-Elhamid, & Hussein, 2017). The predominant amino acid in muscle of Californian breed male rabbits is glutamic acid, followed by threonine, valine, methionine, isoleucine, leucine, phenylalanine, histidine and lysine (Nutautaitė, Racevičiūtė-Stupelienė, Bliznikas, & Vilienė, 2023). In contrast, lysine is the dominant essential amino acid in muscle of e.g. New Zealand White and Balady rabbits (Morshdy et al., 2022). In general, the content of some essential amino acids, such as histidine and phenylalanine, may differ significantly between different rabbit genotypes within the main breeds (Nasr et al., 2017). The amino acid profile of rabbit meat also varies with feeding regime, inclusion of bioactive compounds in the feed and weaning age (Bivolarski et al., 2011; Colin & Ghezal-Triki, 2001; Simonová et al., 2018). Because the amino acid profile of muscle is related to meat flavour and nutritional value (Moeller et al., 2010), manipulation of external factors such as type of feed, dietary supplements and weaning age can be used to improve sensory quality of rabbit meat.

Rabbit meat is also a potential source of bioactive peptides with antihypertensive and antioxidant properties. Several bioactive peptides with strong angiotensin-I-converting enzyme (ACE) inhibitory activities have been identified in rabbit meat and have been chemically characterised (Chen, Yu, Chen, Wu, & He, 2022; Chen, Yu, Huang, Wang, & He, 2021).

Carnosine Related Compounds (CRCs), mainly carnosine, homocarnosine, anserine and *N*-acetylcarnosine, are defined histidine containing peptides with a strong activity against glycation and oxidation. Rabbit meat is a good dietary source of anserine, which predominates in

a white type of meat (Peiretti et al., 2011). While mammalian tissues are generally abundant in taurine (2-aminoethanesulfonic acid), rabbit meat is relatively low in this conditionally non-protein essential amino acid, thus the animal's diet should be supplemented to increase its concentration.

5.2. Fat and fatty acids

Rabbit meat is considered healthier than other types of meat because of its lower content of saturated fat and particularly cholesterol. The total cholesterol content in rabbit meat ranges from 48 to 60 mg/100 g (Adeyemi et al., 2022; Cavani, Petracci, Trocino, & Xiccato, 2009), depending on the breed and muscle type. This is comparable to the level in ostrich meat (Sales, 1998) and beef (Wood, 2023) and lower than that in mutton/lamb, pork, chicken and turkey (Cavani et al., 2009; Wood, 2023). Among the breeds available in Ukraine, meat from White Giant and hybrid rabbits (White Giant X Belgian Giant X New Zealand White) has the lowest cholesterol levels, 40 and 30 mg/100 g, respectively (Kotsyubenko & Petrova, 2011). Cholesterol content and fatty acid composition can be further improved by adjusting the diet of farmed rabbits, since in monogastric animals, including rabbits, the fatty acid composition of the meat at least partly reflects that in the diet. There have been numerous attempts to increase the content of PUFA in meat and reduce the cholesterol content (Table 3). It has been shown that cholesterol content can be reduced by dietary inclusion of dried *Plukenetia conophora* seeds (Adeyemi et al., 2022), dried *Laurus nobilis* leaves (Palazzo et al., 2020), amaranth oilcake (Shevchik, Duda, Gavrilina, Kuneva, & Samoyluk, 2021) and linseed (Mattioli et al., 2020). These feed ingredients also improve the fatty acid composition of the meat. Insect-based additives have also been tested in rabbit diets for their effect on fatty acid composition. It has been found that e.g. use of silkworm oil as a dietary ingredient increases the content of PUFA in hind leg muscle, liver and peri-renal fat in rabbits (Dalle Zotte et al., 2022). Addition of iodine preparation in a dose of 0.35 mg/kg to rabbit feed has also been shown to increase the content of some PUFA in meat, but it should be noted that only 10 rabbits were used in that study (Yakubchak, Zabarna, Taran, Prosaniy, & Dzhmil, 2018).

The ratio of n-6/n-3 PUFA is another important quality indicator of food, because the balance of those fatty acids in the diet affects cardiovascular health in humans. The ratio of n-6/n-3 in rabbit meat depends strongly on dietary ingredients and ranges from 0.02 (rabbits fed a sunflower supplement) to 7.4 (rabbits fed a fish oil supplement) (Bernardini, Dal Bosco, & Castellini, 1999). The n-6/n-3 ratio has also been found to be modified to a more nutritionally favourable value by replacing beef tallow in rabbit feed with linseed oil (Tres, Bou, Codony, & Guardiola, 2008). In one study, the PUFA content in rabbit meat was significantly reduced by inclusion of *Moringa oleifera* leaves in the diet, but the proportion of total n-3 was higher and the ratio of n-6/n-3 was lower in those rabbits (Bhatt, Sarkar, Sharma, & Soni, 2023). Dietary inclusion of individual plant bioactive compounds in rabbit feed can also modify fatty acid composition and other meat quality parameters (Shuo Li, Wu, Zhao, Chen, & Chen, 2023; North, Dalle Zotte, & Hoffman, 2019). Thus, modification of the ratio of n-6/n-3 by dietary means is an attractive strategy to improve rabbit meat quality. The possibilities and advantages of different dietary supplements for enrichment of rabbit meat in terms of n-3 PUFA warrant further investigation.

5.3. Minerals and vitamins

Rabbit meat contains higher levels of potassium, calcium and phosphorus than beef, pork and chicken (Cavani et al., 2009; Nistor et al., 2013). The average sodium content in rabbit meat is relatively low, 49.5 mg/100 g in foreleg muscle and 37 mg/100 g in the loin (Cavani et al., 2009). The sodium content in meat of other species is much higher, e.g. 65–89 mg/100 g in beef, 70–84 mg/100 g in pork and 65–86 mg/100 g in poultry meat (Cavani et al., 2009; Hermida, Gonzalez, Miranda, & Rodríguez-Otero, 2006).

The content of iron is lower in rabbit meat than in red meats such as beef, lamb, horse and ostrich (Dalle Zotte, 2014) and similar to the content in pork and poultry (Lombardi-Boccia, Martinez-Dominguez, & Aguzzi, 2002). Total iron content in raw rabbit meat reported in different studies varies from 0.45 to 1.16 mg/100 g (Króliczewska, Miśta, Korzeniowska, Pecka-Kiełb, & Zachwieja, 2018; Lombardi-Boccia et al., 2002; Valenzuela et al., 2011). This variation is likely due to different genetic background of the rabbits in those studies and different sampling site in the rabbit carcass. For example, Valenzuela et al. (2011) found the highest iron content in the foreleg (0.99 mg/100 g), followed by the hind leg (0.83 mg/100 g) and the loin (0.66 mg/100 g). Approximately half of the total iron content in rabbit meat is haem iron, which is more easily absorbed by the human intestine than non-haem iron (Króliczewska et al., 2018).

Rabbit meat is a good source of bioavailable B vitamins. Compared with other meat types, rabbit meat has a higher content of vitamin B_{12}, up to 12 mg/100 g lean edible portion (Dalle Zotte & Szendrő, 2011). The vitamin E content in rabbit meat is comparable to that in other meat types, but only trace amounts of vitamin D have been found in rabbit meat (Dalle Zotte & Szendrő, 2011).

Table 3
Summary of findings in recently published studies (2021−2023) investigating the effects of dietary supplementation with bioactive compounds on the quality of rabbit meat.

Ingredient	Amount	Duration of experimental period	Breed and gender	Site of measurement	Effect on cholesterol	Effect on PUFA* content	Reference
Freshwater *Cladophora glomerata*macroalgal biomass	4% and 8%	70 days	Californian breed male rabbit	Longissimus thoracis et lumborum (LTL) and hind leg muscles	No effect	Increase	Nutautaitė et al., 2023
Moringa oleifera leaves	70% and 95%	47 days	Chinchilla male rabbits	LTL	Not determined	Decrease	Bhatt et al., 2023
Mealwormfrass	1%, 2% and 3%	11 weeks	Gabali male rabbits	Thigh meat	No effect**	Decrease	Radwan et al., 2023
Acerola by-product	8%, 16%, 24% and 32%	50 days	New Zealand x California male and female rabbits	LTL	No effect	Not determined	Tavares et al., 2022
Silkworm oil	13 g/kg	3 weeks	Pannon White breed. Information on gender not available	Hind leg muscle, liver, and peri-renal fat	Not determined	Increase	Dalle Zotte et al., 2022
Amaranth oilcake	20%	60 days	Californian breed male and female rabbits	Meat (muscle not specified)	Decrease	Not determined	Shevchik et al., 2021

* PUFA: polyunsaturated fatty acids.
** Cholesterol levels measured in blood plasma.

6. Sensory quality and consumer attitudes to rabbit meat

The main sensory quality aspects affecting consumer perceptions of rabbit meat are appearance, juiciness, tenderness and flavour. The composition of flavour compounds is particularly important for the sensory parameters of meat and for consumer acceptance. The specific pleasant smell and taste of rabbit meat are believed to be due to relatively high proportions (up to 1.5–2.0% in raw meat) of nitrogenous compounds (creatinine, carnosine, purine and inosine monophosphate) and nitrogen-free compounds (glycogen and sugars) (Kotelevych, 2019).

Consumer attitudes to rabbit meat are influenced by many factors, including social values, cultural determinants and quality perceptions. The main drivers and barriers to rabbit meat consumption have been the focus of several recent studies. Attitudes to consumption of rabbit meat differ between countries (Szendrő, Szabó-Szentgróti, & Szigeti, 2020). In China, consumer willingness to purchase rabbit meat has been found to be associated with general eating habits, purchase location and personal knowledge (Wang, Shen, Cai, Liu, & Gai, 2022). The origin of rabbits is an important factor for consumers in Italy, France, Hungary and Brazil, with consumers preferring beef, lamb and pork over rabbit meat in all four countries (Szendrő et al., 2020). Rabbit rearing with limited use of antibiotics and good animal welfare are reported to be the main factors affecting consumer purchasing choices in Italy (Crovato et al., 2022). In some countries, including Sweden, rabbit meat is rarely consumed because of rabbit popularity as pets.

Only a limited number of studies on this issue have been performed by Ukrainian researchers, but all have underlined the high sensory properties of the meat. Sensory characteristics, including taste, tenderness, juiciness, colour and aroma, of meat from Californian and Belgian Giant breeds have been found to score 4.6 to 5.0 on a 5-point evaluation scale (where 5 is highest), while broth from the same meat received scores from 4.8 to 5.0 (Kotelevych, 2019). Rabbit genotype (Nasr et al., 2017) and housing systems (Krunt et al., 2022) were reported to have limited or no impact on the sensory characteristics of the meat.

Generally, the majority of the consumers in Ukraine have a positive attitude to rabbit meat and considered rabbit meat as tasty and healthy.

7. Health effects of rabbit meat consumption

Consumer preferences are now being re-directed toward healthy foods from sustainable production systems. Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in humans around the world, and there is evidence of an association between red and processed meat consumption and the risk of CVD (Micha, Wallace, & Mozaffarian, 2010). Management of cardiovascular risk factors, such as lifestyle and a balanced healthy diet, can reduce the risk of CVD in humans.

Rabbit meat can be considered a healthy food due to its leanness and desirable fatty acid profile. In many Eastern European countries, rabbit meat is recommended as part of a healthy diet for children, pregnant women and the elderly. As underlined by Hermida et al. (2006), the low sodium and high potassium content make rabbit meat particularly beneficial in the diet of consumers with hypertension. Moreover, the bioactive peptides with strong angiotensin-I-converting enzyme (ACE) inhibitory activities identified in rabbit meat (Chen et al., 2021, 2022), relatively high anserine content (Peiretti et al., 2011), as well as ubiquinone related compounds Q10 and Q9 (Szkucik, Pyz-Lukasik, Wojcik, & Gondek, 2013) could help reduce the risk of CVD and implement the antioxidant status. For example, tests in a rat model of the antihypertensive effects of the bioactive peptide WGAP from rabbit meat have shown that this compound can significantly reduce systolic and diastolic blood pressure in hypertensive individuals following oral administration (Chen et al., 2021). The lower saturated fat, cholesterol and haem iron concentrations in rabbit meat can also help prevent the development of CVD, as well as atherosclerosis and hypertension. Thus, replacement of beef and pork with rabbit meat could decrease the risk of CVD in the same way as shown for consumption of chicken meat (Bernstein et al., 2010). This should be confirmed in future studies. Further improvement of rabbit meat products regarding their healthiness could be achieved through addition of bioactive compounds to the diet or through incorporation of bioactive ingredients during meat processing (Dalle Zotte & Szendrő, 2011).

8. Possibilities of new rabbit meat-based products

Currently, the rabbit meat industry faces the challenge of reduced consumption globally and particularly in Ukraine due to military actions. Market-oriented approaches in food innovations and the development of new rabbit products are important. Ukraine has a rich history of recipes based on meat. Sausages and sausage-like products are popular foods in Ukraine (Bondar & Golikova, 2022; Nyankovskyy et al., 2014). Such products are currently mainly based on pork and chicken or other conventional types of meat. Rabbit meat is used to a lesser extent in sausage production, and is mainly recommended for children (Koralevsky, Karapandzha, Shapoval, Radchenko, & Legat, 2019; Krychkovska et al., 2019). Dumplings with rabbit meat have also been developed for school children (Tishenko & Tkanka, 2017). The rabbit meat market could be broadened by introducing more rabbit sausages and other processed products, such as burgers and nuggets. Low-fat fresh sausage made from rabbit meat can be an attractive option to meet consumer demands for low-fat products with attractive sensory characteristics (Honrado, Aínsa, Marquina, Beltrán, & Calanche, 2022). A rabbit meat chorizo developed in one study was highly accepted by consumers (Leines, Hernández, Hernández, & Rodríguez, 2018). A product based on rabbit meat with addition of white bean paste developed by Molokanova and Lukomskiy (2014) also received high scores by the Ukrainian consumers. Development of new Ukrainian brand products from rabbit meat adapted to the needs of the market and effective marketing communication would be helpful in supporting the national economy in the post-war period.

9. After-war challenges with welfare issues, new technology needs and feedstuff

As we have shown in Fig. 1, the vast majority of rabbit meat is produced in households. In fact, they do not require large investments (Lukefahr et al., 2004). Therefore, they can quickly resume production. It is necessary to provide them with veterinary medicines, but this is not a big problem. The issue of animal welfare is less relevant for such households. They keep their animals in good conditions, but they are mainly interested in the economic viability of production.

Industrial enterprises have not suffered significant damage so far, so the issue of their restoration is not relevant. In the post-war period, it is unlikely that such enterprises will actively start introducing new approaches to animal welfare. However, given that Ukraine has committed to implementing EU requirements in this regard, such work will be carried out. It is unclear how intensively the new regulations will be implemented and depends, among other things, on the government's position (availability of a relevant government programme, etc.).

10. Conclusions

Rabbit production in Ukraine is a promising area of economic activity and in coming years this segment could increase further to become a significant segment in the domestic economy. Rabbit meat production has good potential in terms of nutritional value, consumer preferences and sustainability aspects. However, for the long-term development of rabbit production, it is necessary to carefully evaluate the present situation of rabbit farms in Ukraine, attract investment resources, introduce effective innovative technologies and follow animal welfare and meat quality standards.

CRediT authorship contribution statement

Galia Zamaratskaia: Conceptualization, Investigation, Methodology, Formal analysis, Visualization, Writing – review & editing. **Oleksandr Havrysh:** Investigation, Methodology, Formal analysis, Visualization, Conceptualization, Writing – review & editing. **Malgorzata Korzeniowska:** Investigation, Methodology, Formal analysis, Visualization, Writing – review & editing. **Andriy Getya:** Conceptualization, Investigation, Methodology, Formal analysis, Visualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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