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Assessment of the information to consumers on insects-based products (Novel Food) sold by e-commerce in the light of the EU legislation: When labelling compliance becomes a matter of accuracy.

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Abstract

Edible insects are an alternative protein source with environmental, social and health benefits. Insect-based products (IBPs), considered as Novel Foods by the EU legislation, are mainly sold on the EU market through e-commerce. In this study, the current situation of the EU IBPs e-commerce was characterized by i) identifying Food Business Operators involved in the selling and ii) assessing the IBPs’ compliance to the EU labelling requirements. Overall, 26 e-commerce platforms were identified, mainly with head offices located in North and Central Europe and 656 IBPs proposed to be sold online were found. Most of IBPs consisted of whole insects (54.9%), followed by protein products (9.5%) and powder insects (8.1%). IBPs made with House cricket (A. domesticus) (50.2%) were the most represented. Overall, only 3.4% of the IBPs were fully compliant with the EU labeling requirements. The high level of non-compliance was mainly related to the absence, incompleteness or inaccuracy of the “additional specific labelling requirements” imposed by Implementing Regulations authorizing the placing on the EU market of IBPs, probably due to their recent entrance in force. Among these, issues related to allergens’ declaration observed in many IBPs reflected possible safety implication for consumers. This study, by providing useful data on the FBOs involved in e-commerce of IBPs and describing the main IBPs categories sold on the EU online market, could also support the Competent Authorities towards more targeted official control activities.

Keywords: Labelling, online products, Novel Food, edible insects, alternative protein source, allergic risk.
1. Introduction

It is predicted that the world population will reach 9.7 billion by 2050 (FAO, 2021), creating an increasing demand for animal-protein sources (Henchion et al., 2017; Van Huis & Oonincx, 2017). However, traditional food production systems are among the major causes of global warming, especially for what concerns livestock (Gerber et al., 2013; Herrero et al., 2016; Van Huis, 2020). For these reasons, many studies have investigated new and sustainable animal-protein sources, and edible insects have been considered a promising alternative (Henchion et al., 2017). On the one hand, the environmental impact of these production is lower than those of poultry, swine and especially cows (Nedeau et al., 2015; Oonincx & De Boer, 2012; Van Huis & Oonincx, 2017). Indeed, the production of 1 kg of edible protein of mealworm (Tenebrio molitor) has a Global Warning Potential (kg CO2-eq/kg edible protein) 1.3 to 2.7 times less than chicken meat and 5.5 to 12.5 times less than beef (Nedeau et al., 2015; Oonincx & De Boer, 2012). Moreover, this species requires less water and land to produce the same quantity of protein than pigs, chicken, and beef (Miglietta et al. 2015; Nedeau et al., 2015; Oonincx & De Boer, 2012). In addition, Smentana et al. (2015), who compared the main types of meat substitutes with respect to their environmental impact, observed that insects - together with soy-based products - had the lowest environmental impact. On the other hand, some edible insects – such as crickets and mealworms - have significantly healthier Nutrient Value Score than beef and chicken (Payne et al., 2016).

The potential of edible insects as food explains the increasing global attention on entomophagy (Toti et al., 2020; Van Huis et al., 2013; Van Huis, 2020). In the last decade, insect industry sector has grown worldwide (Mancini et al., 2022; Sogari et al., 2023) and, also in the European Union (EU), the expected output should reach 260,000 tons of insects-based products (IBPs) by 2030 (IPIFF, 2020; Mancini et al., 2022; Żuk-Golaszewska et al., 2022). The IBPs should especially consist of whole insects, insect ingredients (e. g. powder) and products with insect’
ingredients added, such as protein/energy bars, burgers, pasta, and bakery products (Mancini et al., 2022; Pippinato et al., 2020). However, acceptance rates of EU consumers towards edible insects are still low (Kornher et al., 2019), and different studies investigating entomophagy highlighted disgust and high food neophobia (also described as novel food fear) mainly in Westerners (La Barbera et al., 2018; Mancini, Sogari et al., 2019, Sogari et al., 2019). Therefore, their integration into the EU countries’ diets appears a distant perspective (Onwezen et al., 2019; Rumpold and Langen, 2019). In this respect, reducing the insects’ powder and visibility by using them as ingredients for IBPs has been proposed as a valid option to overcome rejection and resistance to insects’ consumption (Tzompa-Sosa et al., 2023).

According to the EU regulatory framework, edible insects fall under the definition of Novel Food, i.e. “any food that was not used for human consumption to a significant degree within the Union before 15 May 1997” as provided by the Regulation (EU) No 2015/2283, also called Novel Food Regulation. According to this regulation, the European Commission (EC) can authorise a company to sell a Novel Food on the EU market if not cause a safety risk to human health and does not mislead the consumer. Because of that, the applicant producer needs to provide a scientific dossier which undergoes a risk assessment by the European Food Safety Authority (EFSA) (Sogari et al; 2023). Once the risk assessment is positively concluded, the EC authorizes the commercialization as Novel Food, such in the case of IBPs (Pisanello & Caruso, 2018). The formal authorization consists of issuing a Commission Implementing Regulations (CIRs) that add new approved Novel Food to the “Union List of Novel Food”. Currently, there are six CIRs authorizing four Food Business Operators (FBOs) to place on the EU market different types of IBPs, which can be made with four edible insect species, namely yellow mealworm (Tenebrio molitor), migratory locust (Locusta migratoria), house cricket (Acheta domesticus), lesser mealworm (Alphitobius diaperinus) (Table 1). The CIRs explain the food categories (e. g. frozen, dried, powder forms, etc.) that can be commercialized, and
the maximum level of insect allowed for each category. Additionally, they include the so-called “additional specific labelling requirements”, that must be implemented by FBOs, integrating the mandatory information required by Article 9 of the Regulation EU No 1169/2011 on the provision of food information to consumers. The same labelling requirements must be also implemented by FBOs who sell foods by “distant selling method”, according to the Article 14 (“distance selling”). In this case, all the mandatory information must be provided to the consumer before the conclusion of the purchase, except for the date of minimum durability or the “use by date”, that shall be provided only when products are delivered (Reg. EU No 1169/2011)).

Among distance selling methods, e-commerce, is the trading of goods and services using Internet (Jain et al., 2021). Currently, it is the most common way to sell IBPs on the EU market (Pippinato et al., 2020). To note, however, that it was reported as an important way of distribution of not authorized Novel Food on the EU market (DGSANTE, 2019). Based on this, and according to the Article 10.2 of the Regulation (EU) 2017/625, the Competent Authority (CAs) should produce (with periodical upgrades) a list of FBOs acting through e-commerce and places them under their control. However, past surveys conducted by CAs in different EU member states found that updating the FBOs’ list and identifying unregistered FBOs operating online was a difficult task (DGSANTE, 2019).

Considering the evolution of the recent IBPs’ regulatory framework (Table 1), this study represents a preliminary attempt to characterize the current situation of the IBPs e-commerce in the EU. In particular, the aim was to identify FBOs who sell authorized IBPs on the EU market by e-commerce platforms and assess the IBPs’ compliance to the labelling requirements established by EU legislation. Results from this study can support the CA in listing the FBOs acting in this sector and can make it more aware of the main non-conformities in the field of IBPs’ labelling.
2. Materials and Methods

2.1 E-commerce platforms selection

An Internet search was conducted from November 2022 to January 2023 using Google, Microsoft edge and different combinations of keywords: “Insect* AND (edible OR food* OR snack*) AND shop*” to identify e-commerce platforms offering IBPs authorized by the EU CIRs (Table 1). The search was also facilitated by the identification of Bug Burger (https://www.bugburger.se/), a Swedish container blog proposing a list of e-commerce platforms selling IBPs. The e-commerce platforms were selected only if: 1) the head office was in an EU member state, or in the UK and Switzerland, and 2) they sell IBPs in the EU.

2.2. Selection of IBPs sold on the e-commerce platforms

IBPs were selected within the e-commerce platforms previously identified, in the period from the beginning of February to the beginning of June 2023. Only pre-packaged products were chosen. For each selected IBP, the product’s sheet information and the label photos (when available, complete, and legible) found on the dedicated web page were translated from the original language to English using "Google Translate". The selected IBPs were grouped within 19 commercial macro-categories (CMs) - from “A” to “S” (described in Table 2) – which were obtained by merging some “specified food category” (with relative FoodEx2code, when available) indicated in the CIRs (Supplementary Material 1). For example, the categories "dried whole insect" and "frozen whole insect" were merged into the same CM “A”, i.e. *frozen and dried whole insect*, as in both cases insects were present in whole form.

2.3 IBPs labelling assessment

The compliance of the selected IBPs to the "mandatory information of the Regulation EU No 1169/2011" and to the “additional specific labelling requirements” of the CIRs was assessed (Table 3). The IBP was considered as compliant if each information was both present and reported in the correct way (label accuracy). Respect to the information "name of the food", it
was especially evaluated if the “legal name” reported (required by Regulation EU No 1169/2011) matched with “designation of the novel food” reported in the “additional specific labelling requirements” established by the respective CIR. In the absence of this, at least the presence of the “descriptive name” (Article 17.1 of the Regulation EU No 1169/2011) was checked. According to the International Platform of Insects for Food and Feed (IPIFF) guidelines, regarding the provision of food information to consumers for IBPs (IPIFF, 2019), the “descriptive name” should be “sufficiently clear to inform the consumer about the nature of the products or ingredients at stake”. Therefore, we considered that the “common name” of the insect, its “scientific name” and the “commercial form” related to the “food category” used (e.g. dried, frozen, etc.), should be provided. Regarding the information “allergens”, besides the Regulation EU No 1169/2011 requirements, the presence and accuracy of the following statement “this ingredient may cause allergic reactions to consumers with known allergies to crustaceans, molluscs, and products thereof, and to mites”, reported by the “additional specific labelling requirements” of the CIRs, was assessed. In the absence of the aforementioned indication, the presence of a generic warning regarding allergy risk for individuals with known allergies to crustaceans, molluscs and dust mites was evaluated.

Results and discussion

3.1 E-commerce platforms selection

A total of 26 e-commerce platforms selling IBPs in the EU were selected. The head offices were distributed in Germany (n=4; 23.5%), France (n=4; 23.5%), Belgium (n=3; 17.6%), Denmark (n=3; 17.6%) and UK (n=3; 17.6%); the remaining nine (34.6%) in other six EU member states, two of which in Italy (Figure 1). These results show a prevalent distribution of the e-commerce platforms head offices in Central and Northern EU member states (n=17; 65.4%). This agrees with a previous study evaluating the scenario of the EU edible insect industry, which reported that e-commerce platforms selling IBPs were mainly distributed in
UK, Germany, France, and Denmark (Pippinato et al., 2020). In this respect, people from North
Europe show greater affinity for entomophagy with respect to other Europeans (Menozzi et al.,
2017; Piha et al., 2018; Siddiqui et al., 2023). Furthermore, e-commerce is more used for
purchasing food in Northern EU member states such as the Netherlands, Estonia, UK,
Lithuania, and Germany (DGSANTE, 2019). The Netherlands and Belgium are currently
considered leaders in the EU edible insect sector (Mancini et al., 2019b, Siddiqui et al., 2023),
with several farms and industries located in their territory (Baiano et al., 2020; Mancini, Sogari
et al., 2019; Pippinato et al., 2020). These two member states are nevertheless the first Western
nations to permit edible insects on the market (Siddiqui et al., 2023). Indeed, the willingness to
consume IBPs by citizens from the Netherlands and Belgium was especially highlighted in the
literature (Mancini, Moruzzo et al., 2019; Toti et al., 2020; Tzompa-Sosa et al., 2023). Despite
this, a relatively low number of e-commerce platforms was found to have their head office in
these two countries in this study, also accordingly to Pippinato et al. (2020) that show a low
percentage of e-commerce selling IBPs in the Netherlands.

The good predisposition towards the consumption of insects has been considered a cultural
factor (Deroy et al., 2015; Mancini et al., 2022; Moruzzo et al., 2021). For example, it was
observed that societies with a strong gastronomic culture had a higher rejection of
entomophagy (Mancini, Sogari et al., 2019; Mancini et al., 2022; Menozzi et al., 2017; Toti et
al., 2020, Siddiqui et al., 2023). Indeed, the low presence of e-commerce platforms selling IBPs
with head office in Mediterranean member states (e.g. Spain and Italy), could depend on the
cultural importance of the Mediterranean diet, which is recognized by the United Nations
Educational, Scientific and Cultural Organization (UNESCO) as an Intangible Cultural
Heritage of Humanity (Poli et al., 2019), as it assumes an important anthropological role in the
daily life of citizens (Poli et al., 2019; Toti et al., 2020). A study conducted by Ros-Baró et al.
(2022) on Spanish consumers’ willingness to eat edible insects further confirms this
assumption. Indeed, it was highlighted that 86.9% of participants had never consumed insects and were unwilling to cook them (71.0%) or include them in their usual diet (82.2%). Despite this, 58.3% of consumers considered entomophagy to be an adoptable practice in the future, opening possibilities for future acceptance (Kornher et al., 2019).

3.2 Selection of IBPs sold on the e-commerce platforms

3.2.1. IBPs’ distribution among the different CMs. According to the literature, edible insects are mainly consumed in the EU in whole or powder form, sold as they are (100% insect) or used as food ingredients into final products (e.g. energy and protein bars, burgers, bread, bakery products and pasta) (Acosta-Estrada et al., 2021; IPIFF, 2020; Mancini et al., 2022;). Regardless of this, by 2025, it is expected a reduction of the whole insects’ products market share (10% of the entire market), counterbalanced by an increasing presence of products where edible insects’ presence is less evident or that are more familiar to EU consumers (IPIFF, 2020).

However, our results show that whole insects are still the most spread type of IBPs, at least with respect to the e-commerce platforms analysed in this study. Although IBPs are mainly sold in the EU by e-commerce (Pippinato et al., 2020), it should be however underlined that these data reflect a partial market overview, being other selling ways excluded.

The selected IBPs were overall 656, included in 14 of the 19 pre-established CMs. The majority of CMs even didn’t achieve 5% of the total IBPs. Only five CMs contained over 5% of the total selected IBPs and only one of these went over 10%. As mentioned before, the most representative CM was "frozen and/or dried whole insect (A)" containing 54.9% (n=360) of the IBPs, followed by "protein products (other than meat substitutes) (C)" (i.e. protein bars, protein mixtures and protein chips) (9.5%; n=62), "powdered insect (partially defatted and not) (B)" (8.1%; n=53) and "bakery products and premixes (G)" (6.9%; n=45). Surprisingly, no IBPs were found for the CMs "meat substitutes (E)" and only one IBP for the CMs “meat products (meat or meat products) (D)” (i.e. meat-balls, meat-burger and sausages only partially made
up with edible insects), even though edible insects were usually considered and presented to the consumers as valuable meat alternatives (Onwezen et al., 2021; Smentana et al. 2015). To note that, according to IPIFF, meat substitute products on the EU market are going to increase until 2025 (+46%) (IPIFF, 2020) and different studies have been conducted about their technological and nutritional properties (Acosta-Estrada et al., 2021). For example, *T. molitor* and *A. domesticus* powders were used to partially replace meat in some meat products, and *A. diaperinus* powder was added to vegetable protein to produce meat substitute products (Acosta-Estrada et al., 2021). However, to support our findings, other studies suggested that in the developed countries food neophobia causes unwillingness to accept the direct substitution of meat with dishes exclusively made with insects (Mancini et al., 2022). Even consumers with the intention to reduce meat consumption are not always willing to replace it with edible insects (Mina et al., 2023; Modlinska et al., 2021). Anyway, in the last years, the acceptance for these types of IBPs is suggested to be in general higher than whole insects (Alhujaili et al., 2023; Castro & Chambers, 2019; Mancini et al., 2022; Ros-Barò et al., 2022; Toti et al., 2020; Tzompa-Sosa et al., 2023), probably explaining the predicted evolution of the EU IBPs’ market. As not to exclude that the higher quota of whole insects IBPs found in our study can be associated with the ludic interest in the consumption of such types of “exotic” foods. In addition to the above reasons, the SARS-CoV2 pandemic, having a major impact on dietary choices (Siddiqui et al., 2023), has probably slowed down and changed the way the market was expected to develop. Indeed, this pandemic has especially generated a debate regarding wildlife trade with some suggestions about possible limitation or ban to the activity of entomophagy (Halabowski & Rzymski, 2020; Siddiqui et al., 2023). Furthermore, Khalil et al. (2021) found that the pandemic caused a decrease in willingness to consume IBPs in a sample of Spanish consumers. Factually, the known causes of the pandemic themselves should be instead a call
to search for alternative protein sources, including IBPs, to decrease the risk of zoonotic
transmission, as suggested by Rzymski et al. (2021) (Siddiqui et al., 2023).

Finally, no IBPs were found for the CMs "processed potato products (L)"", "soup (N)"", "salads (O)" and "milk products and dairy products (P)". Regarding the last CM, we have to consider that the acceptance of insects as food is influenced also by consumers' perception of the appropriateness of their usage as an ingredient (Tan et al., 2016). Indeed, the study conducted by Tan et al. (2016) on the Dutch population found that participants considered, for instance, meatballs appropriate as a food which included insects as ingredients, while they rated milk products (especially beverages) as inappropriate. Therefore, companies producing an IBP should take this evidence into account when selecting the food categories to propose for approval, as different food carriers have elicited different levels of consumer willingness to purchase (Alhujaili et al., 2023; Tan et al., 2016).

3.2.2 Edible insect’s species distribution of the selected IBPs. Most of the analyzed IBPs were made with *A. domesticus* (50.2%; n=329), followed by *T. molitor* (32.9%; n=216), *A. diaperinus* (9.1%; n=60), and *L. migratoria* (7.2%; n=47). Only, two IBPs (0.6%) consisted of a mix of all the four species and two IBPs of a mix of *A. domesticus* and *T. molitor*.

As previously evaluated by Pippinato et al (2020), this distribution shows that the most sold IBPs through e-commerce in the EU are made with *A. domesticus* and *T. molitor*, which together correspond to more than 80% of the IPBs, while a more marginal role is played by *A. diaperinus* and *L. migratoria*.

Authorised IBPs novel food made with *T. molitor* and *A. domesticus* could be placed on the EU market by the applicant and associated business partners since 2021 (CIR (EU) 2021/882) and 2022 (CIR (EU) 2022/188), respectively, probably explaining why they are most widespread than authorised IBPs novel food of *A. diaperinus*, which was permitted only in 2023 (CIR (EU) 2023/58). Moreover, the spread IBPs made with *A. domesticus* and *T. molitor* could be
facilitated by the presence of different studies describing their advantages in terms of environmental sustainability, breeding and production (Van Huis & Tomberlin, 2017), food safety aspects (Van Huis et al., 2013, Imathiu, 2020; Toti et al., 2020) and technological and nutritional properties (Acosta-Estrada et al., 2021; Finke, 2002; Rumpold & Schulter, 2013; Van Huis et al., 2013;). Notwithstanding, IBPs made with *L. migratoria* are the lesser diffused on EU market, even though a Novel Food application was positively evaluated and authorized in 2021 (CIR(EU) 2021/1975), and *L. migratoria* properties as food have been widely evaluated (Mohamed, 2015). This species is known to have a weedy nature, capable of destroying entire herbaceous crops, especially in warmer regions (Scanlan et al., 2001). Moreover, it feeds almost exclusively on herbaceous biomass (Scanlan et al., 2001) and weight losses, cannibalism cases and increasing mortality have been observed when a poor diet, such as organic waste or plant by-products, is provided (Van Peer et al., 2021). All these factors could influence FBOs' choice to produce IBPs based on *L. migratoria* and explain their low diffusion on the EU market.

Despite *A. diaperinus*, is easy to rear and appreciated for its nutritional and health characteristics, *T. molitor* is preferred for food production (Van Huis & Tomberlin, 2017). In addition, *T. molitor* larvae’s microbial flora seems to be able to reduce and contrast *Salmonella* spp. infections (Islam & Yang, 2017; Wynats et al., 2019). On the other hand, adult form of *A. diaperinus* is considered pest in different establishments of the agri-food chain (Van Huis & Tomberlin, 2017), and some studies highlighted the persistence of some zoonotic strains of *Salmonella* spp. within its larvae (Van Huis, & Tomberlin, 2017; Wynats et al., 2018). Therefore, IBPs made with this species are probably lesser widespread than those made with *T. molitor* and *A. domesticus* because FBO’s need to apply more control systems during the farming phase. In fact, according to Van Huis & Tomberlin (2017), most of the work on *A. diaperinus* was conducted with the aim of minimizing their proliferation and controlling
pathogen transfer as much as possible. Finally, as explained before, application of the marketing of IBPs made with *A. diaperinus*, were the last authorized.

### 3.2.3 Distribution of IBPs among the CMs and respect to the insect species

These results are summarized in Figure 2, and more detailed in Table 4. *A. domesticus* and *T. molitor* were used IBPs belonging to 10/14 CMs (71.4%), *A. diaperinus* in 9/14 CMs (64.2%) while IBPs of *L. migratoria* in 3/14 (31.4%). The CM “frozen and/or dried whole insect (A)” was the most represented for all the species (range %), except for *A. diaperinus* (%) that was especially used to produce “Protein products (other than meat substitutes) (C)” (28.3% n=17). Surprisingly, this latter CM did not include IBPs made with *T. molitor* and *L. migratoria*, even though both these species were considered high in protein, especially *L. migratoria* (Acosta-Estrada et al., 2021; Clarkson et al., 2018; Mohamed, 2015; Rumpold & Schulter, 2013). In addition, for both the species, the chemical and technological properties of their proteins have been extensively studied, as well as those of *A. domesticus* and *A. diaperinus* (Acosta-Estrada et al., 2021; Bußler et al., 2015; Clarkson et al., 2018; Purschke et al., 2018).

The following CMs: “frozen and/or dried whole insect (A)”, “powdered insect (partially defatted and not) (B)” and “Chocolate products (J)” where those in which all the species were used. In addition to other factors that will be discussed in section 3.2.2, the almost total absence of processed IBPs made with *L. migratoria* could be a price matter. According to the literature, some EU consumers express a low willingness to pay for IBPs (Mina et al., 2023) and IBPs made with *L. migratoria* have higher sales price than IBPs made with the other species, even within the same food category. For instance, we noticed that prices of *L. migratoria* powder were more expensive than *T. molitor, A. domesticus* and *A. diaperinus* powders. For instance, the price of 1Kg of *L. migratoria* powder varied from 378.00 € to 905.30 €, depending on the seller. Thus means that 1 Kg of *L. migratoria* powder cost the double of 1 Kg of *A. domesticus* powder sold by the same e-commerce platforms and from 4 to 9 times more than 1 Kg of *T.
molitor or A. diaperinus powders. In this early market stage, focusing on consumers willing to pay more for IBPs seems a more promising strategy: initial high prices may create consistent demand curves (Berger et al., 2018), permitting the development of the market that, together with the increase in consumer familiarity with edible insects, will permit lower prices (Mina et al., 2023).

3.3 IBPs labelling assessment

Several authors agreed that sharing information about IBPs can increase consumers’ acceptance (Alhujaili et al., 2023; Mancini, Sogari et al., 2019; Mancini, Moruzzo et al., 2019; Mina et al., 2023; Siddiqui et al., 2023; Sogari et al., 2019b; ;). Particularly, information related to the nature of the food, nutritional properties, origin healthiness of the insects used as ingredients, and ethical-environmental advantages should decrease consumers’ food neophobia (Clarkson et al., 2018; Hartmann et al., 2018; Mancini, Moruzzo et al., 2019; Mancini et al., 2022; Verneau et al., 2016). Even though the role of informative session about those aspects needs to be further investigated (Alhujaili et al., 2023), communication through the IBPs’ label could also have an important role into the increasing of the acceptance for IBPs of EU consumers. Moreover, a correct labelling has a key role for consumers’ safety, as contributing to prevent eventual economic fraud and a potential allergenic risk for the consumer (Garino et al., 2022).

In this study, only 3.4% (22/656) of the IBPs were found to be fully compliant with the considered EU labelling requirements. The remained 96.6% was found non-compliant and IBPs non-compliance rate per species was very similar and ranging from 95.4% to 100% (Table 5).

3.3.1 Labelling assessment of the mandatory information of the Regulation EU No 1169/2011”: The percentage of compliance for each “mandatory information of the Regulation EU No 1169/2011” can be overlaid between IBPs of the different species (Figure 3). Among those, the least present information was the "instructions for use" that were considered
unnecessary in most of the selected IBPs, because of their nature. Indeed, according to Article 9, j) of the Regulation EU No 1169/2011, this information is required “where it would be difficult to make appropriate use of the food in the absence of such instructions”. However, although none of the CIRs contained "additional specific labelling requirements" related to instructions for use, CIR (EU) 2021/1975 states that "with regard to frozen L. migratoria and dried L. migratoria, the legs and wings should be removed to reduce the risk of constipation, which could be caused by ingestion of the large spines present on the insect tibia”. Respect to this, although there is no specific obligation, the wording "remove wings and legs before consumption" was present in 38.5% (n=5) of the IBPs made up with this species. The information “Storage condition” was present in 57.6% of the total selected IBPs (n = 378) (Figure 3), which specifically reported to store the product in cool and dry place. Indeed, edible insects are susceptible for microbiological hazards if proper heat treatment or storage conditions are not applied (Klunder et al., 2012), especially involving bacteria such as Enterobacteriaceae and sporulating bacteria (Klunder et al., 2012). According to literature, a heating step (blanching) is sufficient for inactivation of Enterobacteriaceae, but not spore of sporulating bacteria (Cappelli et al., 2020; Vandeweyer et al., 2017) that cannot be fully significantly reduced by any heat treatment, according to the literature review proposed by Cappelli et al. (2020). However, Vandeweyer et al. (2017) showed that no microbial growth occurred during refrigerated storage and microwave drying after a blanching treatment. Therefore, edible insects need to be processed and stored with care, and accurate labelling information about this aspect are essential for safety of consumers.

The information “Quantity of certain ingredients or categories of ingredients” (QUID) was present in 61.1% out of the 505 IBPs in which it was mandatory (308/504). In this respect, according to a specific Commission Notice of 2017 (CN, 2017), this information is not mandatory for foods consisting of a single ingredient. Thus, no evaluation of this information was
performed in IBPs 100% consisting of insects, such as not-flavored whole insects (99 IBPs) and insect powder (53 IBPs).

According to the Article 26 of the Regulation EU No 1169/2011, the indication of the “Country of origin or place of provenance” shall be mandatory when failure to indicate it might mislead the consumer, such as when the labelling information presents some origins claims. Therefore, the IBPs’ compliance with this information was assessed only in those cases. Indeed, the information was present in 79.4% of the total selected IBPs (n=521), of these, 517 IBPs were associated with origin claims, resulting totally compliant.

3.3.2 Labelling assessment of the “additional specific labelling requirements” established by CIRs: The high rate of non-compliance found in this study was mainly related to the complete absence, incompleteness, or inaccuracy of the “additional specific labelling requirements” about “the name of the food” and the “allergen’s statements” imposed by CIRs, as shown in Figure 4 and Figure 5. In fact, it was observed that, not considering the "additional specific labelling requirements" during the labelling assessment, the non-compliance rate dropped from 96.6% to 72.4% (475/656). This condition could be associated to the detailed statements provided by the “additional specific labelling requirements” established by the newest labelling regulation on IBPs (Table 1 and Table 3).

Specifically, in 92.1% of the IBPs (n=604), the “legal name” of the food does not match the “designation of the novel food” established by the CIRs. As previously described, in the absence of a “legal name”, a “descriptive name” should be provided on the label (Article 17.1 of Regulation EU No 1169/2011). In this respect, the "descriptive name" (composed as described in section 2.3) was present between 60.2% and 70.5% of the selected IBPs among the different species and products (Figure 4).

For instance, all the selected IBPs made with A. diaperinus (n=60) were considered non-compliant because the accurate “legal name”, established by in CIR (EU) 2023/58, was never
Indeed, the most used “name of the food” found in the selected IBPs label included the terms "buffalo worm" which is popularly considered the “common name” of this species but not the legal once required (i.e. "lesser mealworm"). In addition, the recent promulgation of the CIRs could have affected the labelling compliance rate. In fact, IBPs made with A. diaperinus, which are the ones with the highest non-compliance rate (Table 5), were the most recently insect-based novel food authorized to be placed on the EU market (CIR (EU) 2023/58, published on 5 January 2023), probably confirming that IBPs’ producers are still living an adaptation phase to the newest labelling requirements.

In particular, 76.2% (n=500) of the IBPs presented at least the “scientific name” of the edible insect species used to produce them (Figure 4). Indeed, before CIRs implementation, IBPs made with mealworms, grasshoppers and crickets had already been sold on the European market (Fischer & Steenbekkers, 2018; Pippinato et al., 2020), but no "additional specific labelling requirements" had yet been established. For this reason, although the overall labelling assessment highlighted a high level of non-compliance with respect to the “name of the food”, it is considered that the presence of an appropriate “descriptive name” in most of the IBPs provided to the consumer sufficient information to fully understand the nature of those products. However, it is considered important that the legal names pursuant to the CIRs should be adopted in a short time.

Besides the “legal name”, the precise “allergens’ statement” established by CIRs was also absent in most IBPs (n=398; 60.1%) (Figure 5). Food allergies due to the consumption of insects can occur in individuals with known food allergies to crustaceans, molluscs, or dust mites (Cappelli et al., 2020; EFSA, 2015; Francis et al., 2019; Garino et al., 2022; Papastavropoulou et al., 2023; Siddiqui et al., 2023; Srinroch et al., 2015; Van Huis et al., 2013; Van der Fels-Klerx et al., 2018; Van Huis, 2020). Indeed, correct labelling is considered essential to communicate and manage the sanitary risk associate with food allergen substances, as explained by...
EFSA in its “Scientific Opinion on the evaluation of allergenic foods and food ingredients for labelling purposes” (EFSA, 2014), as also stated by Garino et al. (2022) respect to insects as food. For this reason, IPIFF recommends that FBOs placing IBPs on the market include a general warning indication about this health risk on the label of their products (IPIFF, 2019). In this regard, appropriate (even though not accurate) general warning indication were present in 88.3% (n=579) of the IBPs. For this reason, although from a purely regulatory point of view the products were considered as non-compliant, the general warning indications provided could have protected the consumer from allergy risk due to IBPs consumption.

3.3.3 Labelling information about the origin of the insects. Regarding this information, it was declared only in 43.0% of the selected IBPs (n=282), showing that, according to Pippinato et al. (2020), there is a general information deficit about this aspect. Moreover, the Article 26.3 of the Regulation EU No 1169/2011 establishes that the "Country of origin or place of provenance of the primary ingredient” should be provided when is not the same of the food (IBPs). Therefore, the origin of the insects was considered mandatory only for those IBPs present into the CMs “Frozen and/or dried whole insect (A)” and “Insect powder (partially degreased and not) (B)”. In this regard, only 44.1% of the total IBPs in these CMs (182/413) presented the origin of the insects, being compliant to the labelling requirements. Finally, 23.4% (66/282) of the IBPs reporting the origin of the insects declared a non-EU origin, namely Thailand, Canada, UK, USA and Switzerland (Figure 6). Accordingly, with the entry into force of CIR (EU) 2021/405 (Annex XV), Canada, South Korea, Switzerland, Thailand, and Vietnam have been allowed to the entry of insects into the EU. In addition, the origin of edible insects from Asian countries is probably also associate with their wide distribution in this part of the world, so much so that in 2019 Thailand, China, and Vietnam owned 41% of the global income of this sector (Mancini et al., 2022). Currently, UK, and USA are not on the list of third countries that may import insects or their parts into the EU market, so at present there should be no IBPs on
EU market containing insects from these countries. Despite this, 24.2% (16/66) of IBPs with insect of a non-European origin come from UK and 22.7% (15/66) of them come from USA. Curiously, no IBPs have been detected with claimed insects from Vietnam, as far as EU law would allow.

3. Conclusion

In this study, an overview of the current EU IBPs’ e-commerce, which is the most widespread selling method of this novel food, was provided. Moreover, this study provides information on the different IBPs food categories currently present on the EU e-commerce. The observed high rate of non-compliance was mainly attributed to the lack of completeness, accuracy, or adequacy of the “additional specific labelling requirements” imposed by CIRs. However, it was considered that the result was probably influenced by the recent introduction of these regulations and their extremely detailed requirements as regards legal name and allergens’ statement. Hence, the high number of IBPs with non-compliant labels is probably due to a phase of adaptation to the new legislation by the FBOs. In any case, being these "additional specific labelling requirements" fixed to guarantee the consumers’ protection by preventing food safety issues, a future FBOs adaptation is required. Considering the rapid market evolution, and also the available market prediction, these data should be further assessed in the coming years. Finally, thanks to the identification and listing of the main FBOs active in this sector we provide useful data to assist the CAs in draw up and up-to-date list of operators as required by the EU legislation on official controls.

Acknowledgements:

This work is supported by the Università di Pisa under the "PRA – Progetti di Ricerca di Ateneo" (Institutional Research Grants) - Project no.13 PRA_2022-2023 _ "Next Generation
Sequencing per la valutazione del rischio in food e feed a base di insetti (NGS-Ins)”. In addition, authors wish to thank Dr. Niccolò Fonti for his graphical advises.

Figures caption

**Figure 1**: Distribution of e-commerce platforms among EU member states. Number and colour assigned for each EU member state correspond to the number of e-commerce platforms with head offices in that country.

**Figure 2**: Sankey diagram representing the distribution of insect-based products (IBPs) among the commercial macro-categories (CMs) and respect to the insect species. The thickness of connection between the insect species and the CM reflect the number of products.

**Figure 3**: Percentage of insect-based products (IBPs) reporting each mandatory information requested by the Regulation EU No 1169/2011. For the information “Name of the food” both the “legal name” and the “descriptive name” were evaluated. TOT = total number of IBPs.

**Figure 4**: Percentage of insect-based products (IBPs) presenting the “Legal name”, the “Descriptive name” and the “Scientific name” overall and divided for each species. Each column represents the percentage of IBPs, facet for edible insect species, presenting the “Legal name”, the “Descriptive name” and the “Scientific name” on the label. TOT = total number of IBPs.

**Figure 5**: Percentage of insect-based products (IBPs) presenting the “Allergens’ general warning indication” and the “Allergens’ statements” established by the CIRs, divided for each species and overall. Each column represents the percentage of IBPs, facet for edible insect species, presenting the “Allergens’ general warning indication” and the “Allergens’ statements” on the label. TOT = is related to the total number of IBPs.

**Figure 6**: Sankey diagram illustrating the “Origin of insect” declared for the selected IBPs. The thickness of connection between the insect species and the CM reflect the number of products.

References


Commission Implementing Regulation (EU) 2023/5 of 3 January 2023 authorising the placing on the market of Acheta domesticus (house cricket) partially defatted powder as a novel food and amending Implementing Regulation (EU) 2017/2470 (Text with EEA relevance); C/2023/6; OJ L 2, 4.1.2023, p. 9–14

Commission Implementing Regulation (EU) 2023/58 of 5 January 2023 authorising the placing on the market of the frozen, paste, dried and powder forms of Alphitobius diaperinus larvae (lesser mealworm) as a novel food and amending Implementing Regulation (EU) 2017/2470 (Text with EEA relevance); C/2023/20; OJ L 5, 6.1.2023, p. 10–15


EFSA (2015). Risk profile related to production and consumption of insects as food and feed. EFSA journal, 13(10), 4257. https://doi.org/10.2903/j.efsa.2015.4257


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Modlinska, K., Adamczyk, D., Maison, D., Goncikowska, K., & Pisula, W. (2021). Relationship between acceptance of insects as an alternative to meat and willingness to consume insect-based...


Table 1: List of Commission implementing Regulation (CIRs) which currently authorize the place of insect-based products (IBPs) on the EU market. For each regulation the insect species and food categories authorized are reported.

<table>
<thead>
<tr>
<th>Commission implementing Regulation (CIR)</th>
<th>IBPs’ species and food categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIR (EU) 2021/882</td>
<td>dried <em>Tenebrio molitor</em> larva (yellow mealworm)</td>
</tr>
<tr>
<td></td>
<td>frozen, dried and powder forms of</td>
</tr>
<tr>
<td></td>
<td><em>Locusta migratoria</em> (migratory locust)</td>
</tr>
<tr>
<td></td>
<td>frozen, dried and powder forms of</td>
</tr>
<tr>
<td></td>
<td><em>Acheta domesticus</em> (house cricket)</td>
</tr>
<tr>
<td></td>
<td>frozen, dried and powder forms of</td>
</tr>
<tr>
<td></td>
<td>yellow mealworm (<em>Tenebrio molitor</em> larva)</td>
</tr>
<tr>
<td>CIR (EU) 2022/188</td>
<td>frozen, paste, dried and powder forms of <em>Alphitobius diaperinus</em> larvae (lesser mealworm)</td>
</tr>
<tr>
<td></td>
<td><em>Acheta domesticus</em> (house cricket)</td>
</tr>
<tr>
<td></td>
<td>partially defatted powder</td>
</tr>
</tbody>
</table>
Table 2: Commercial macro-categories (CMs) obtained by merging the “food category” reported in the Commission Implementing Regulations (CIRs) which authorize the place of insect-based products (IBPs) on the EU market (see Supplementary Material 1).

<table>
<thead>
<tr>
<th>Commercial macro-categories (CMs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frozen and/or dried whole insect (A)</td>
</tr>
<tr>
<td>Insect powder (partially degreased and not) (B)</td>
</tr>
<tr>
<td>Protein products (other than meat substitutes) (C)</td>
</tr>
<tr>
<td>Meat products (meat or meat products) (D)</td>
</tr>
<tr>
<td>Meat substitutes (E)</td>
</tr>
<tr>
<td>Legume and vegetable products (F)</td>
</tr>
<tr>
<td>Bakery products and premixes (G)</td>
</tr>
<tr>
<td>Cereal biscuits and bars (H)</td>
</tr>
<tr>
<td>Pasta products (dried) (I)</td>
</tr>
<tr>
<td>Chocolate products (J)</td>
</tr>
<tr>
<td>Sauces (K)</td>
</tr>
<tr>
<td>Processed potato products (L)</td>
</tr>
<tr>
<td>Snacks of various types (M)</td>
</tr>
<tr>
<td>Soups (N)</td>
</tr>
<tr>
<td>Salads (O)</td>
</tr>
<tr>
<td>Milk products and dairy products (P)</td>
</tr>
<tr>
<td>Nuts, oilseeds and chickpeas (Q)</td>
</tr>
<tr>
<td>Fermented and non-fermented alcoholic beverages (R)</td>
</tr>
<tr>
<td>Other(S)</td>
</tr>
</tbody>
</table>
**Table 3**: Insect-based products (IBPs) labelling information that was assessed in this study, with relative legislative reference.

<table>
<thead>
<tr>
<th>Analyzed information</th>
<th>Mandatory information (Regulation EU No 1169/2011)</th>
<th>additional specific labelling requirements (CIRs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the food</td>
<td>art.14; art. 9 a); art. 17; all.VI</td>
<td>Annex I</td>
</tr>
<tr>
<td>List of ingredients</td>
<td>art.14; art. 9 b); art. 18; art. 19; art. 20</td>
<td>does not contain requirements in the CIRs</td>
</tr>
<tr>
<td>Allergens</td>
<td>art.14; art.9 c); art.21; Appendix II</td>
<td>Annex I</td>
</tr>
<tr>
<td>Quantity of certain ingredients or categories of ingredients (QUID)*</td>
<td>art.14; art. 9 d); art. 22; all. VIII</td>
<td></td>
</tr>
<tr>
<td>Quantity of the food</td>
<td>art.14; art. 9 e); art. 22; all. IX</td>
<td></td>
</tr>
<tr>
<td>Storage condition</td>
<td>art.14; art. 9 g); art. 25</td>
<td></td>
</tr>
<tr>
<td>the name or business name and address of the FBO responsible for the labelling</td>
<td>art.14; art. 9 h); art. 7; art.8</td>
<td>does not contain provisions in the CIRs</td>
</tr>
<tr>
<td>Country of origin or place of provenance*</td>
<td>art.14; art. 9 i); art. 26</td>
<td></td>
</tr>
<tr>
<td>Instructions for use*</td>
<td>art.14; art. 9 j); art. 27</td>
<td></td>
</tr>
<tr>
<td>Nutrition declaration</td>
<td>art.14; art. 9 l); art. 30; art. 32; all. XV</td>
<td></td>
</tr>
<tr>
<td>Country of origin or place of provenance of the primary ingredient (Origin of the insects)*</td>
<td>art. 26</td>
<td></td>
</tr>
</tbody>
</table>

*This information was assessed for IBPs for which they were considered mandatory, according to the Regulation EU No 1169/2011.*
**Table 4:** Distribution of insect-based products (IBPs) among commercial macro-categories (CMs), overall and for each species. CMs = “Frozen and/or dried whole insect (A)”; “Insect powder (partially degreased and not) (B)”; “Protein products (other than meat substitutes) (C)”; “Meat products (meat or meat products) (D)”; “Meat substitutes (E)”; “Legume and vegetable products (F)”; “Bakery products and premixes (G)”; “Cereal biscuits and bars (H)”; “Pasta products (dried) (I)”; “Chocolate products (J)”; “Sauces (K)”; “Processed potato products (L)”; “Snacks of various types (M)”; “Soups (N)”; “Salads (O)”; “Milk products and dairy products (P)”; “Nuts, oilseeds and chickpeas (Q)”; “Fermented and non-fermented alcoholic beverages (R)”; “Other (S)”.

For each species is indicated the number of IBPs found on e-commerce platforms for each CM. %CM/TOT: percentage of the total selected IBPs in each CM.
<table>
<thead>
<tr>
<th>CM</th>
<th>T. molitor</th>
<th>A. domesticus</th>
<th>L. migratoria</th>
<th>A. diaperinus</th>
<th>mix</th>
<th>Tot.</th>
<th>% CM/TOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>149</td>
<td>156</td>
<td>40</td>
<td>11</td>
<td>4</td>
<td>360</td>
<td>54.9%</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>20</td>
<td>6</td>
<td>12</td>
<td>0</td>
<td>53</td>
<td>8.1%</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>45</td>
<td>0</td>
<td>17</td>
<td>0</td>
<td>62</td>
<td>9.5%</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0.15%</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>34</td>
<td>5.2%</td>
</tr>
<tr>
<td>G</td>
<td>8</td>
<td>33</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>45</td>
<td>6.9%</td>
</tr>
<tr>
<td>H</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>23</td>
<td>3.5%</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>10</td>
<td>1.5%</td>
</tr>
<tr>
<td>J</td>
<td>13</td>
<td>14</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>4.6%</td>
</tr>
<tr>
<td>K</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>1.1%</td>
</tr>
<tr>
<td>L</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0.5%</td>
</tr>
<tr>
<td>N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.3%</td>
</tr>
<tr>
<td>R</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0.6%</td>
</tr>
<tr>
<td>S</td>
<td>13</td>
<td>7</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>3.4%</td>
</tr>
<tr>
<td>Tot.</td>
<td>216</td>
<td>329</td>
<td>47</td>
<td>60</td>
<td>4</td>
<td>656</td>
<td></td>
</tr>
</tbody>
</table>
Table 5: Percentage of IBPs with non-compliance label divided for insect species. Number of IBPs is the number of IBPs made with the corresponding edible insect species. %IBPs Non-compliant: is the percentage of IBPs made with each edible insects species presenting labelling no-compliance, corresponding to the non-compliance rate.

<table>
<thead>
<tr>
<th>IBPs'edible insect species</th>
<th>Number of IBPs</th>
<th>% IBPs Non-compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. domesticus</td>
<td>329</td>
<td>95.4% (314 PBI)</td>
</tr>
<tr>
<td>T. molitor</td>
<td>216</td>
<td>97.2% (210 PBI)</td>
</tr>
<tr>
<td>L. migratoria</td>
<td>47</td>
<td>97.9% (46 PBI)</td>
</tr>
<tr>
<td>A. diaperinus</td>
<td>60</td>
<td>100% (60 PBI)</td>
</tr>
<tr>
<td>Mix</td>
<td>4</td>
<td>100% (4 PBI)</td>
</tr>
<tr>
<td>TOT</td>
<td>656</td>
<td>96.6% (634)</td>
</tr>
</tbody>
</table>
• Insect-based products (IBPs) sold on EU e-commerce platforms were selected.
• The compliance of IBPs labelling information to EU legislation was assessed.
• Most IBPs were non-compliant, especially respect to requirements of CIRs.
• Outcomes from this study could support official controls.
Declarations of interest: none