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Results of an International Survey for Risk Assessment of Honey Bee Health Concerning Varroa Management

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Abstract: Here, we present the results of an online international survey concerning the adoption of good beekeeping practices and proper biosecurity measures for the management of varroosis in *Apis mellifera*. The survey was designed as a risk assessment tool by the Food and Agriculture Organization of the United Nations (FAO), the International Federation of Beekeepers' Association (Apimondia), the Center for Analytics Research & Education (CARE) at Appalachian State University, and Istituto Zooprofilattico Sperimentale Lazio e Toscana (IZSLT). The data collected investigated the beekeeping techniques, treatments, and training beekeepers adopt concerning the varroa mite. The idea was to validate a tool able to collect and compare, in the different areas of the world, the management measures adopted by beekeepers to face this major parasitic disease of honey bees. The survey was disseminated online for a period of 14 months (January 2019–March 2020) through the FAO website. A total of 861 responses were received, most of them from the Americas (20.9%) and Europe (74.7%). Concerning the control measures useful in combating varroa, the results showed an overall awareness of the usefulness of biosecurity measures in beekeeping (BMBs), which we compare across regions. The majority of the beekeepers (89.9% in the Americas and 82.8% in Europe) were interested in additional bee health training and, at the same time, were willing to connect themselves with veterinary experts specialized in bees. This is an indication that beekeepers recognize the importance of training and experts' advice. This study revealed the efficacy of the survey adopted as a useful assessment tool that will be further disseminated, even in geographic regions heretofore not investigated, to provide useful information on the status of the beekeeping sector.

Keywords: biosecurity measures in apiculture; good beekeeping practices; honey bees; international survey; risk assessment; varroosis

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1. Introduction

Varroosis is the growing global concern in beekeeping [1–4] since it shifted from the original host, *Apis cerana*, to *Apis mellifera* [5]. It is currently the most prevalent disease of honey bees that contributes to colony losses worldwide [6–16]. Varroa mites [17] are external obligate parasites of the honey bee, which feed on fat body deposits [18,19]. Both small wounds on the cuticle and the depletion of fat bodies make them more vulnerable to other diseases, such as viruses, fungi, or bacteria [20].

Many efforts have been undertaken to identify the best ways to prevent and control varroosis. Beekeepers have various options to control the parasitic varroa mite in honey bee colonies, but no empirical data are available on the methods they apply in practice. Brodschnider et al., 2022 [21], surveyed the set of 19 different varroa diagnosis and control measures in Europe taken from the annual COLOSS questionnaire on honey bee colony

losses. The adoption of integrative activities that beekeepers apply for on-apiary production to attain optimal health for humans, honey bees, and the environment, even called good beekeeping practices (GBPs) [22] and disease-specific biosecurity measures in beekeeping (BMBs) [23], may prevent varroa, improving its control in a sustainable way. In this sense, it reduces the need for the use of veterinary medicines in apiculture, the risk of antimicrobial resistance (AMR), and residues in hive products. Monitoring varroa infestation levels in the bee colonies plays a pivotal role in preventing colonies' losses and properly orienting beekeepers toward the adoption of a sustainable apiculture. Nevertheless, thanks to an integrated pest management (IPM) approach, the effective use of veterinary medicines plays a vital role in the achievement of good honey bee colony management [1,24]. Unfortunately, a one-fits-all control method for varroa control is not available, as each method has its benefits and drawbacks [25]. In addition, currently, there are no alignments among different countries concerning national laws, sanitary regulations, and administrative provisions in beekeeping [24]. However, a good understanding of honey bee biology and pathogens is also required to guarantee the proper management of honey bees.

Online questionnaire surveys are commonly recommended for studies wishing to reach large numbers of people from distant geographical areas, allowing a quantitative approach to examine geographically distinct practices and beliefs [26]. Surveys are also useful tools to periodically reassess those practices after corrective actions have been put into place [27]. Given the importance of varroosis for the beekeeping sector worldwide, this survey, as a risk assessment tool, enabled us to figure out the knowledge of beekeepers on varroosis and its related biosecurity measures, including its prevention and control, as well as on the use of the medicines at the apiary level. This survey was distributed at the international level to monitor beekeepers' knowledge in different regions of the world on the aforementioned topics.

2. Materials and Methods

The original questionnaire, was developed by IZSLT in the context of a letter of agreement with FAO on the antimicrobial resistance in beekeeping and on the responsible use of the veterinary medicines at the apiary level [20]. The content was then adapted and broken out into three separate surveys, antimicrobial resistance [28], varroa management, and infectious disease management, in collaboration with FAO, Apimondia, and Appalachian State University. All the surveys, including this one, were administered online via Qualtrics [29], with voluntary and confidential participation.

The varroa survey was translated into 9 languages: Chinese, Danish, Dutch, English, French, Italian, Russian, Slovenian, and Spanish. It required an internet connection and approximately 10 min to complete. At the end of the varroa survey, respondents could optionally provide their email addresses to receive information and updates on the varroa disease.

The surveys were disseminated through various channels by the collaborators, including the Center for Analytics Research & Education (CARE) at Appalachian State University and by IZSLT. Moreover, targeted emails to over 4650 people, an article in *Bee Culture Magazine*, and promotion through social media were adopted to disseminate it. Additional promotion was provided by multiple affiliated parties, including the beekeeping association APIMONDIA, bee research groups, FAO, CARE, and TECA partners, including La Federación Internacional Latinoamericana de Apicultura (FILAPI) and the Beekeeping Network North-South (BNNS). The goal was to reach as many beekeepers as possible.

The questionnaire (Appendix A) consisted of 25 questions organized into five sections: demographic data (section A), apiary management (section B), varroa knowledge and biosecurity measures adopted (section C), use of antimicrobial use for varroa control (section D), and training (section E).

Measurement levels for most questions were based on Likert scale for categorical variables in addition to Boolean questions with "yes"-or-"no"-style response options. Age, years of experience beekeeping, and estimated number of hives presently managed used

continuous data measures. Some questions used response options: "extremely useful", "moderately useful", "not at all useful", etc. These variables were coded numerically to include a baseline of zero to "not at all useful" and increasing for the highest category.

Section "A" (7 questions) aimed to collect demographic data on beekeepers, including age, gender, education, and the continent where they were located, avoiding any identifying information. Section "B" (4 questions) was designed to collect preliminary information, including years of experience, number of hives managed, frequency of hive inspections, types of hives in use, and hive movement patterns. Section "C" (3 questions) was designed to verify if respondents were able to identify a specific disease depicted in a picture and to assess their knowledge of both the prevention and control measures adopted against varroa. For each practice, respondents were asked to report usefulness as "extremely useful", "moderately useful", or "not at all useful". We coded "extremely useful" = 2, "moderately useful" = 1, and "not at all useful" = 0. The mean values of usefulness of varroa prevention and control measures were coded as relevance scores. Means from 0 to 0.99 were coded as "Low relevance", from 1 to 1.49 were considered as "Medium relevance", and above 1.50 were described as "High relevance" measures. Section "D" (6 questions) assessed different information on acaricides use. The first questions asked beekeepers whether or not they used treatments against varroa mites, and if the answer was affirmative, we asked which medicines were adopted. All commercial products were listed in the respective active ingredients. Moreover, the purchasing channels and limits (prescription) were assessed. A list of biosecurity measures was submitted to respondents to ascertain if they adopted them. In this case, a relevance value was considered as "Low" up to and including 30% (of users who applied the measure), "Medium" within the range of 31–60%, and "High" if more than 60%. Section "E" (5 questions) aimed to gather information on the beekeepers' perceptions regarding training courses, as well as their interest in specific bee health courses.

Statistical Analysis

The methodological approach for the statistical analysis used mean comparisons between the two major continents: the Americas and Europe. There were insufficient responses from other continents to have a statistically valid sample to use for analysis. Due to this factor, the methodological approach was adjusted to only include respondents from those continents. This method allowed us to analyze the main apiary management practices on each continent analyzed, as well as focus on factors that may influence the data. The varroa management control survey was one of the three surveys administered online, and given the requirement for internet access, our sample also contains some sampling bias. The choice of restricting the sample to only American and European respondents helps reduce this issue. T-tests were used to compare central trends in each region, and a minimum significance threshold of $p < 0.05$ was used to assess statistical differences. Given the exploratory nature of this analysis, two-tailed tests were used throughout.

3. Results

Over the 14 months (January 2019–March 2020) of the survey dissemination, a total of 861 users answered the survey, with 89.1% (n = 767) completing the entire survey. An overwhelming majority of responses came from individuals living in the Americas (n = 147) and Europe (n = 525). The data shown below include only the respondents who completed at least 50% of the survey (n = 703). In the next sections, we present the most relevant results of the survey.

3.1. Section A: Demographic Data

The primary languages of the respondents included English (57.8%) and Italian (18.3%), followed by Danish (9.1%), French (7%), Dutch (4.8%), Spanish (2.4%), Russian (0.3%), Slovenian (0.1%), and Chinese (0.1%). Of the initial 703 respondents, most came from Europe (n = 525; 74.7%, of which 37.7% were from the United Kingdom) and the Americas

(n = 147; 20.9%, of which from North America 92.5%; South America 6.1%; and Central America 1.4%), with lower percentages from Africa (1.6%), Asia (1%), and Oceania (0.9%).

Given the low participation from other continents (3.4%), we reported only the results from the Americas and Europe. The most frequent age range of the beekeepers who answered the survey fell between 50 and 69 years (60.4% for the Americas and 54.7% for Europe). The majority of the beekeepers were men, who were slightly more prevalent (71%) in the European sample compared to the American one (63.5%).

The data show high levels of education for the beekeepers in both regions. In fact, most respondents were university graduates, including many post-graduates (68% for the respondents from the Americas and 56.2% for the European respondents). Moreover, a very similar percentage of beekeepers (21.8% for the Americas and 22.3% for the Europeans) attended Vocational, Technical Degree, Associates Degree, or some College. Only 9.5% of the beekeepers in the Americas and 21.1% in Europe had only attended High School or lower levels of education.

Most of the beekeepers had between 0 and 9 years of experience, which was the case for 65.3% of the respondents in the Americas and 58.4% in Europe. Finally, a high percentage of the beekeepers in each of the continents, (85.6%) in the Americas and (83.9%) in Europe, declared themselves as hobby beekeepers rather than professionals.

3.2. Section B: Apiary Management

Concerning the number of colonies managed, a very similar percentage of beekeepers in the Americas (nearly 56%) and Europe (slightly more than 58%) managed between 1 and 10 colonies (see Figure 1). We categorize beekeepers who manage up to ten hives, as "self-consumers", who produce hive products for themselves; the majority of beekeepers in both regions are categorized as such. We further categorize the 42.3 percent of beekeepers in the Americas and 38.6 percent of the beekeepers in Europe who manage 11 or more hives as "production for selling/distribution". Most of the beekeepers in both regions who produce for selling/distribution manage between 11 and 50 hives (33.3% in the Americas compared to 28.6% in Europe). While not reported in the figure, we note that similar percentages of the respondents in the Americas (15.6%) and Europe (18%) were migratory beekeepers.

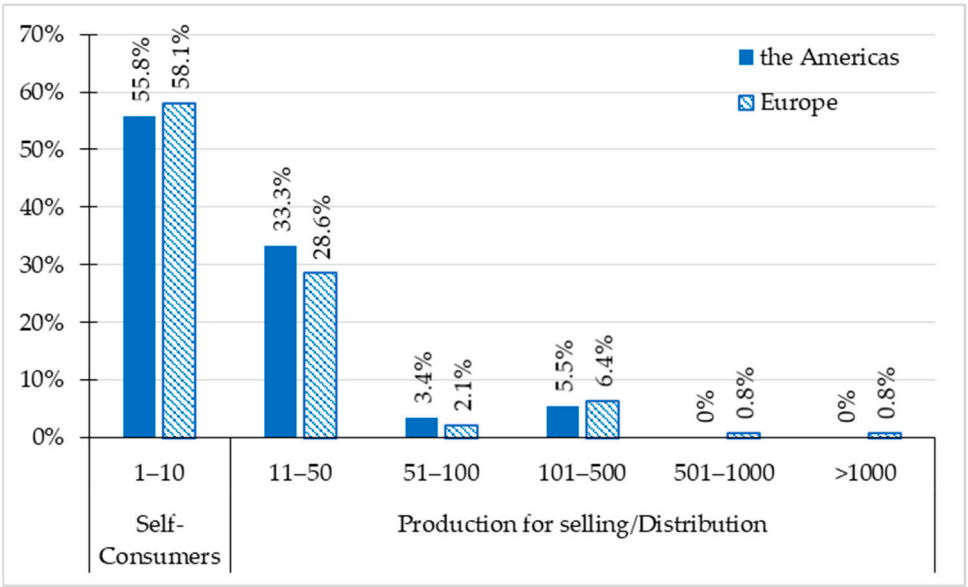

Figure 1. Amount of colonies managed by respondent beekeepers both in the Americas and in Europe. Gathered in two categories, "self-consumers" consisted of beekeepers who produced hive products for themselves and "production for selling/distribution" the beekeepers that sell products.

With regard to the number of the hive inspections during the active season, most beekeepers in the Americas and in Europe inspected the colonies a variable number of times (Table 1). The modal range of the inspections for the beekeepers in the Americas was 2 to 3 times per month (51.7%) and was 4 times per month (38.9%) for those in Europe. Few beekeepers reported never inspecting their hives (1.4% in the Americas and 4.2% in Europe).

Table 1. Number of inspections during the active season both in the Americas and in Europe. The values are expressed in percent (%). Columns exceed 100% due to rounding.

Hives Inspection	The Americas (%)	Europe (%)
More than four times a month	4.1	13.1
Four times a month	21.8	38.9
Two to three times a month	51.7	36.8
Once a month	21.1	7.1
Never	1.4	4.2

3.3. Section C: Varroa Knowledge and Biosecurity Measures Adopted

We also asked questions regarding the knowledge and management of honey bee diseases. Most of the respondents correctly identified the presented picture of varroa mites (98% in the Americas and 97.5% in Europe). For the question on the level of knowledge of varroa and its management, most of the respondents in the Americas and Europe said that they have observed varroa mites in their beehives, while a lower percentage in the Americas (9.5%) and in Europe (2.3%) never saw the mites at all. However, most of the beekeepers who saw varroa multiple times reported they were "moderately knowledgeable" on the disease (45.6% in the Americas and 37.3% in Europe) or "very knowledgeable" about it (23.1% in the Americas and 30.2% in Europe).

Table 2 shows the mean usefulness scores for each prevention and control practice in the Americas and in Europe. "Maintaining the number of varroa below the harmful threshold in each colony" was the most commonly reported practice for both regions, with virtually no differences between the two. "Having good knowledge of the signs of varroosis and virosis" was considered highly useful in both regions but was considered a somewhat more effective prevention and control measure in Europe compared to the Americas (mean 1.81 versus 1.67, $p < 0.05$). The respondents noted high values for "treating swarms (no brood) just after harvest" in Europe (mean = 1.68), with medium values in the Americas (1.32, $p < 0.001$). The practice of "adopting diagnostic tools for measuring varroa infestation levels after treatments and during the year" was considered highly useful in both regions, with significantly higher mean values in the Americas (1.72) compared to Europe (mean = 1.55, $p < 0.01$). "Adopting/providing hives with screened bottom boards" was considered a moderately useful strategy in both regions with the practice considered somewhat more useful in Europe than in the Americas ($p < 0.001$). With the exception of the practices noted above, there were few differences between the Americas and Europe when it comes to the perceptions of the usefulness of varroa preventions and control measures.

3.4. Section D: Antimicrobial Use for Varroa Control

A similar percentage of the respondents from the Americas (81%) and Europe (80.4%) stated that they had treated colonies with medicines against varroa mites in the last 2 years. On the contrary, about 20% of the beekeepers did not treat their bees at all. Figure 2 shows the different approaches concerning the varroa treatments: soft acaricides [1] (thymol, oxalic acid, formic acid, hop acid, and lactic acid) and hard acaricides (Amitraz, Flumethrin, Tau Fluvalinate, and Coumaphos) administered alone or combined. Most of the beekeepers in both continents reported using mainly low-environmental-impact products (55.1% in the Americas and 53.1% in Europe) instead of high-environmental-impact products alone (3.4% in the Americas and 7.8% in Europe). A much lower percentage of beekeepers (17.7% in the Americas and 15.8% in Europe) used a mixture of the two types.

Table 2. Mean values of usefulness of varroa prevention and control measures both in the Americas and in Europe.

Varroa Prevention and Control Measures	The Americas	Europe	Relevance
Maintaining the number of varroa below the harmful threshold in each colony	1.87	1.85	High
Having good knowledge of the signs of varroosis and virosis	1.67 *	1.81 *	
Treating swarms (no brood) just after harvest	-	1.68 ***	
Adopting diagnostic tools for measuring varroa infestation levels after treatments and during the year	1.72 **	1.55 **	
Selecting and breeding queens that are more varroa tolerant/resistant	1.57	1.48	
Treating swarms (no brood) just after harvest	1.32 ***	-	Medium
Nuclei and swarms should originate from colonies with no clinical signs of diseases related with varroa	1.29	1.36	
Adopting/providing hives with screened bottom boards	1.00 ***	1.35 ***	
Providing sufficient number of healthy spare bees at the right time	0.86	0.81	Low

*** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$, mean comparisons between the Americas and Europe.

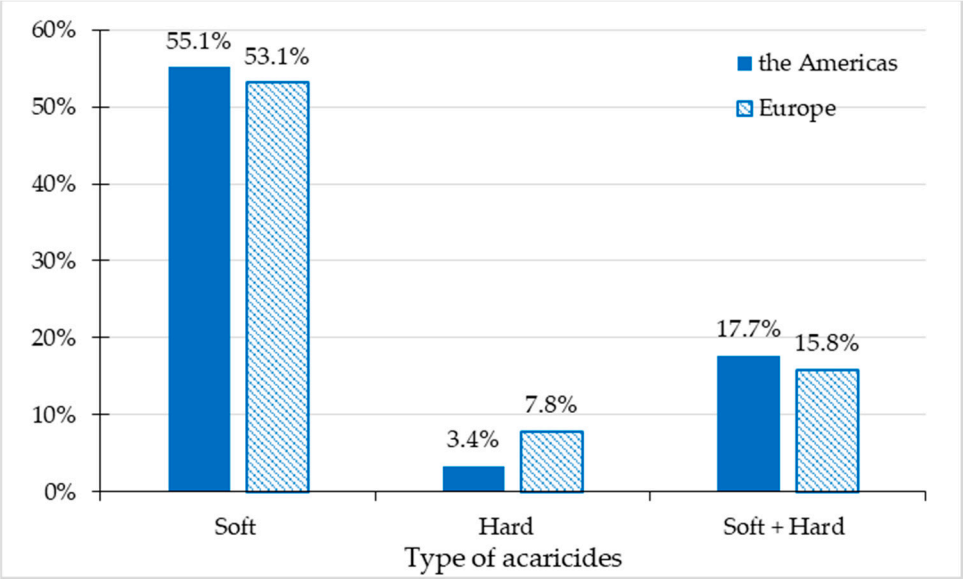

Figure 2. Percentages of use of "Soft" and "Hard" acaricides from respondents both in the Americas and in Europe to treat varroa.

Figure 3 shows the name of the active ingredients used by the respondents during the previous year to treat varroa mites. The highest percentage of beekeepers in Europe (53.9%) reported using soft acaricidal products containing oxalic acid as the active ingredient, followed by those who used thymol (28.8%) and formic acid (27.2%). In the Americas, the highest percentage used formic acid (46.9%), oxalic acid (39.5%), and thymol (29.9%). Another difference in the use of low-environmental-impact products is that only American beekeepers (8.8%) use hop acids. Concerning the use of hard acaricides, instead, about the same percentage of both American and European beekeepers used Amitraz (about 20%), and a lower percentage in each continent used Flumethrin (2%), followed by Tau Fluvalinate (5% in the Americas and 0.7% in Europe). Only 0.8% of the European beekeepers used Coumaphos (Figure 3).

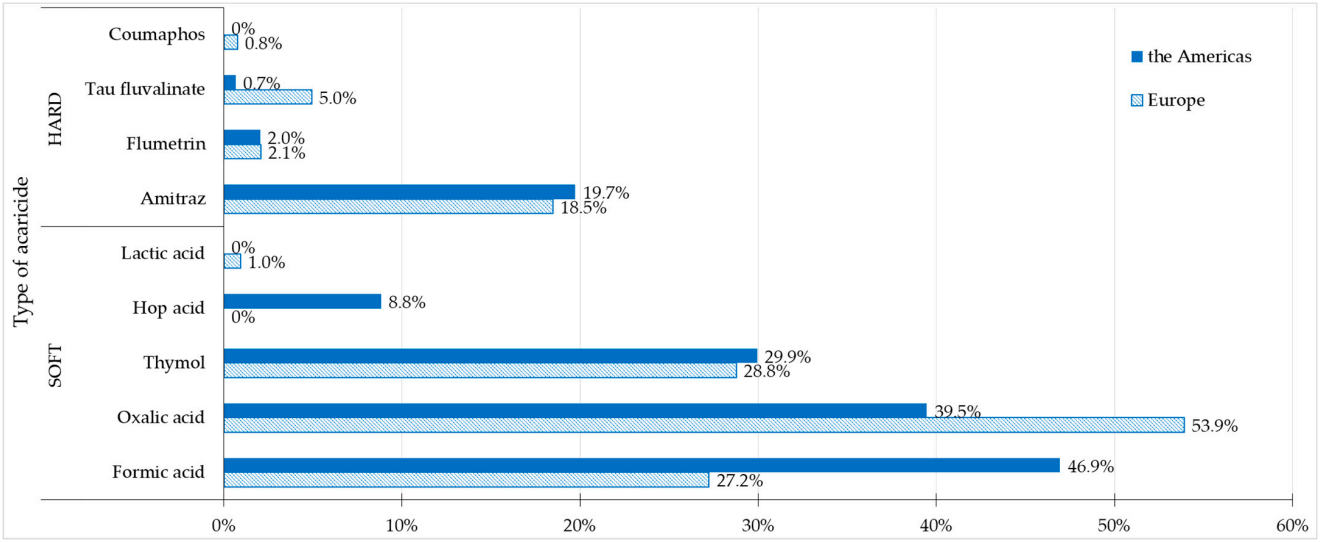

Figure 3. Active ingredients, grouped as "Hard" and "Soft" acaricides, used by American and European beekeepers.

With regard to the number of annually applied treatments for varroa control, a plurality of European (45.2%) and American beekeepers (49.7%) used more than one active ingredient, while a significant percentage of the beekeepers in Europe (31.6%) and in the Americas (26.5%) commonly used only one active ingredient. More specifically, many of the beekeepers used only two active ingredients (30.6% in the Americas, and 32.2% in Europe), a lower percentage used three of them (16.3% in the Americas, and 10.7% in Europe), while only 2.7% of the American beekeepers and 2.3% of the European beekeepers used four active ingredients annually. The vast majority of the respondents (94.1% in the Americas and 82.7% in Europe) stated that they did not need to obtain a prescription to buy varroacides.

As far as acquiring varroacide products, a higher percentage of the American respondents reported obtaining medicines on the internet (36.7%) compared to 23.1% of the Europeans (Table 3). An additional 23.1% of the European beekeepers bought miticides through Agro Chemical Supply or from beekeepers' associations (21.5%). Nearly 26 percent of the beekeepers in the Americas and nearly 17% in Europe purchased medicines in "local bee supply store retailers". A smaller percentage of the users in each continent (4.1% of Americas and 15.8% of Europeans) reported making purchases through Veterinarians, Pharmacies, and extension services.

Table 3. Where the American and European beekeepers purchase medicines against varroa.

Purchasing Channel	The Americas (%)	Europe (%)
Internet	36.7	23.1
Local bee supply store retailers	25.9	16.8
Agro Chemical Supply	15.7	23.1
Beekeepers' Association	8.8	21.5
Other beekeeper	11.6	6.1
Veterinarian	2	7.1
Extension Services	1.4	1.7
Pharmacy	0.7	9

For varroa control, both the European (79.4%) and American respondents (68%) agreed that veterinary medicines should be administered simultaneously to all the hives within the apiary (Figure 4). Similarly, all the respondents agreed on the importance of the adoption of all the "good beekeeping practices" listed in Figure 4, categorized as "Medium" or "High"

relevance. Only one of the procedures listed in the survey, "treat only the varroa affected hives", showed a lower level of agreement, considering the low percentages reached both in the Americas (27.9%) and in Europe (7.8%) (unpublished data).

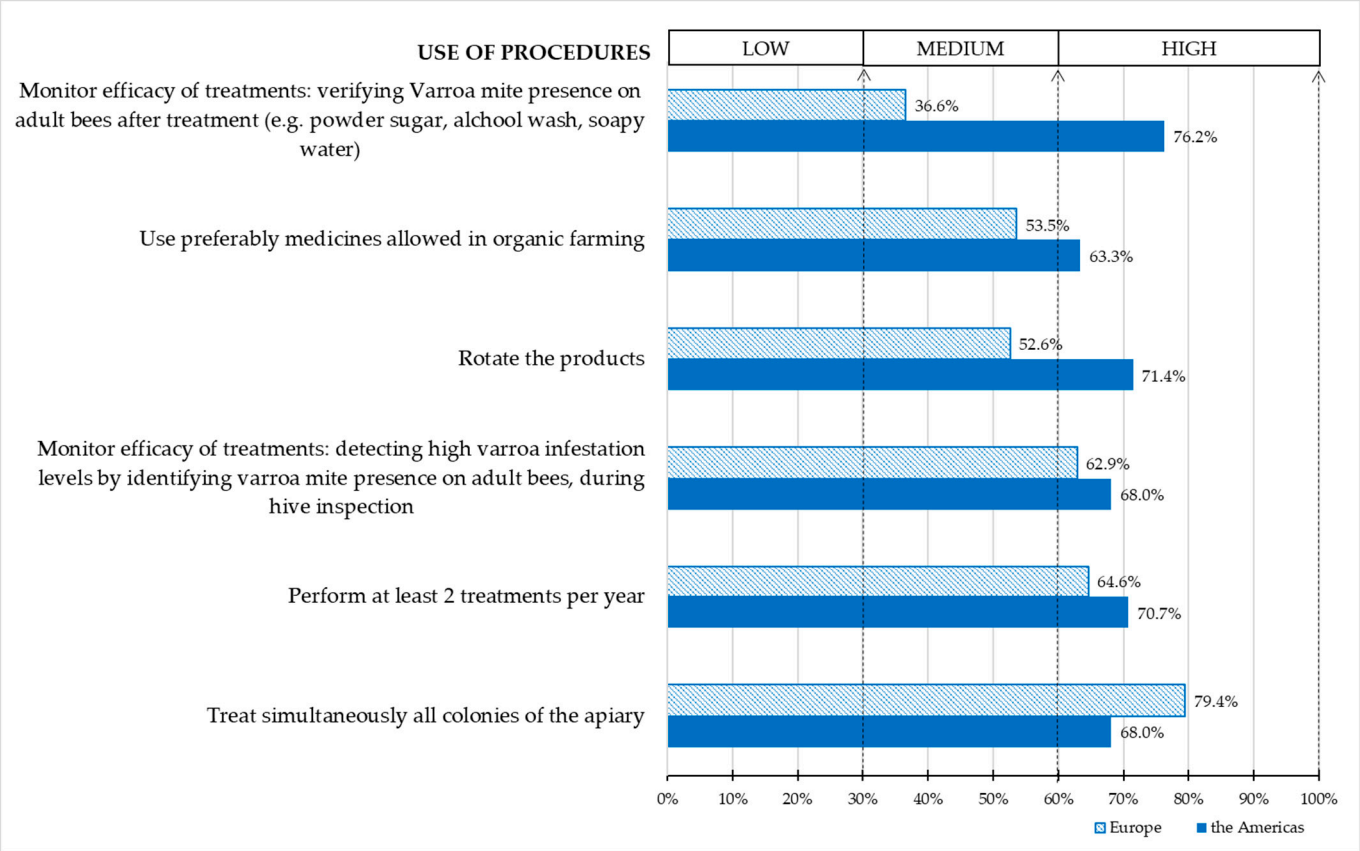

Figure 4. Willingness to accept the listed biosecurity measures by Americans (full blue) and European (blu strips) beekeepers.

Regarding the question on the correct administration of the treatments, the majority of the beekeepers in each continent think that treatments against varroa mites are not carried out correctly following the label instructions. Combining all the categories (from "always" to "sometimes"), about 90% of the respondents indicated that labels were not correctly followed. In detail, the data of American and European beekeepers showed about the same percentages in all categories. On the other hand, only a low percentage (6.9% in the Americas and 8% in Europe) thought that the beekeepers "never" use medicines against varroa without following the label instructions.

3.5. Section E: Training and Interest to Update

Concerning beekeeper training, beekeepers both in the Americas (60.5%) and in Europe (68.4%) attended at least one bee-specific training course; sizeable percentages of the respondents in the Americas (74.1%) and in Europe (79.6%) listed that they know one or more professional beekeeping associations or groups related to bees. Respondents from both the Americas (89.9%) and Europe (82.8%) were interested in additional bee health training courses; however, they would prefer not to attend if the courses are administered online (8.6 and 12.9%, respectively). Beekeepers' interest in connecting themselves with veterinary experts specialized in bees was high for respondents in the Americas (55.3%) and in Europe (60.9%), gathering all the categories of interest analyzed in this survey (from "extremely interested" to "interested"), while a part of the respondents declared themselves "somewhat" interested (respectively, 34 and 25.9%). In comparison, a few American (10.6%)

and European beekeepers (13.8%) were "not at all" interested in a nationwide service that would connect beekeepers with veterinary experts specialized in bees.

4. Discussion

Beekeepers in Europe and in the Americas were most likely to participate in this survey compared to beekeepers in other areas of the world. Reasons for the low participation in some regions likely include more limited internet access or lower connections with other beekeepers (i.e., fewer numbers of beekeepers' associations) and probably linked with a lesser ability to disseminate the survey in some areas, especially in Africa, Asia, and Oceania. Further studies should investigate the most commonly used channels by beekeepers in different regions of the world to increase the number of respondents.

The majority of American (85.6%) and European beekeepers (83.9%) that took part in the survey did not consider themselves professionals, managing between 1 and 10 bee colonies. Even if there is no internationally accepted definition of both these categories (professional and hobbyist beekeepers), we believe that the 1 to 10 colony category falls clearly into the definition of "hobby beekeeper", considering the world average honey production of 20 kg/modern beehives per annum cited in Nuru and Hassan [30]. In each continent, a similar percentage of beekeepers produced hive products for themselves (more than 50%), while about 40% produced products for sale. In addition, most beekeepers (65.3% in the Americas and 58.4% in Europe) had 0–9 years of experience and did not move colonies throughout the years. This is also likely reflective of the low percentage of professional beekeepers in both regions (14.4% in the Americas and 16.4% in Europe), considering that migratory beekeeping is a typical activity for professional beekeepers. Our results are consistent with others [28,31] who find that apiculture is a hobby for the overwhelming majority of the beekeepers in the Americas and in Europe and is not likely a primary source of income; future research should examine whether this is the case in other countries and regions.

Although beekeeping is not limited to a single sex or age group, the ratio of males to females was about 2:1 in each continent analyzed, and most of the respondents were in the 50–69 age range. This is consistent with the age and gender demographics of beekeepers across multiple countries [28,32–34]. The role of women in beekeeping is important and is a possible method of empowering rural women. Even so, beekeeping is a socio-economic activity practiced by both women and men all around the world. Many studies investigated the socio-cultural factors and the influence of gender roles, which affect women's participation in beekeeping [35,36], and clearly this is an area ripe for further exploration.

Although we observe slight differences in the number of inspections among American (51.7%; from 2 to 3 times per month) and European beekeepers (38.9%; 4 times per month), in both regions, beekeeper indicate the importance of providing frequent and regular inspections of the hives [37] during the active season. Even though the varroa mite was usually well known to both American and European beekeepers, unfortunately, there is still a small proportion of beekeepers (1.4% in the Americas and 4.2% in Europe) who do not visit their colonies at all, increasing the risk of spreading honey bee diseases. Further, the beekeepers indicated a number of control measures were useful in combating varroa (Table 2), which was consistent with the recommendations from the team of experts that identified these measures in a previous study [23] as part of the EU SUSAN BPRACTICES project. The control measure "providing sufficient numbers of healthy spare bees at the right time" was considered the worst strategy of choice (low relevance < 1) among beekeepers, in addition to the practice "treat only the varroa affected hives". This suggests that beekeepers do not find these viable options and could suggest reevaluating the list of biosecurity measures for varroa management. Only the option "treating swarms (no brood) just after harvest" had notable differences, assuming a higher relevance among beekeepers in Europe (scored 1.68) than in the Americas (scored 1.32). This could reflect the higher use

of oxalic acid in Europe (very effective on swarms that are broodless) [38] rather than in the Americas.

"Monitoring the efficacy of treatments" and "Treating simultaneously all the colonies of the apiary" were the most accepted practices, respectively, for American and European beekeepers. "Maintaining the number of varroa mites below the harmful threshold" in each colony was considered the high relevance practice both for American and European beekeepers. "Monitoring varroa infestation during the active season" was a common practice noted in several studies [21,25,39,40]; we find that respondent beekeepers in each of the continents appear aware of the importance of monitoring and "adopting diagnostic tools for measuring varroa infestation levels" (e.g., powder sugar, alcohol wash, soap water, etc.).

Concerning the use of acaricides for varroa control, it was well known that the application of veterinary medicines in the "absence of brood" increases the acaricide efficacy for active ingredients that act only on the foretic phase of varroa. In this survey, the majority of the respondent beekeepers (about 80% in each continent) indicated that they have treated colonies against varroa mites in the last two years, and almost half of the beekeepers used more than one active ingredient (49.7% in the Americas vs. 45.2% in Europe). Indeed, rotating the acaricidal products helps avoid long-term varroa resistance, something the respondents in both regions may indeed recognize [41], even if higher attention seemed provided by the American (71.4%) rather than the European beekeepers (52.6%).

In detail, the results showed that among all the active ingredients used by the respondents to treat varroa, more than half of the beekeepers in the Americas and in Europe used mainly soft acaricides alone. Concerning the risk to develop AMR, this seems quite high; 31.6% of the beekeepers in Europe and 26.5% in the Americas treat with only one active ingredient against varroa. The common use of low-environmental-impact products (the "Soft" acaricides used, 55.1% in the Americas and 53.1% in Europe) was ascribed to oxalic acid, thymol, and formic acid in each of the continents. Similar results were observed by other surveys [21,31]. The beekeepers in the Americas are much more likely to use formic acid compared to their European counterparts (46.9 vs. 27.2%), while Europeans were much more likely to use oxalic acid than those in the Americas (53.9 vs. 39.5%). The highest percentage of the use of oxalic acid in Europe [42] is not surprising, given that this active ingredient has been in use for a longer time. The most commonly reported treatment used by beekeepers in the Americas was formic acid (46.9%). Mezher et al. (2021) [31] highlighted the common use of organic acids (formic acid, oxalic acid, and lactic acid) and, at the same time, a reliance on the application of biomechanical methods as well as drone brood removal [21], something not considered in this survey. In Europe, Brodschneider et al. (2022) [21] found that commonly used acaricides included amitraz, thymol, oxalic acid, and formic acid, considering three distinctive clusters of countries in terms of varroa control (given our sample size, this was not possible in our study). Even if our study did not consider the different ways of the application of the veterinary medicines, our findings regarding the common use of oxalic acid in Europe (53.9%) appeared in accordance with this study (69.0% of 28,409 respondents). A very low percentage of American beekeepers (8.8%) used hop acid [43], while in Europe, none of the beekeepers who participated in the survey had ever used veterinary medicines containing this type of active ingredient. This finding is consistent with the list of veterinary medicines recorded for use in beehives to control varroa mites. The Environmental Protection Agency (EPA) authorized the use of Hopguard® [44] in the Americas, while it is not registered in Europe. The beekeepers in our study indicated purchasing medicines on the internet, obtaining them from agro-chemical supply houses, or obtaining them from other local bee supply store retailers. Most of the respondents (94.1% in the Americas and 82.7% in Europe) stated that they do not need to obtain a prescription for medicines against varroa. Unfortunately, in many European Union (EU) countries, most of the medicines registered for honey bees are still sold without any veterinary prescription, making their traceability extremely difficult.

Concerning the proper use of the medicines, the majority of beekeepers think that treatments against varroa mites are not always carried out correctly following the label instructions, both in the Americas and in Europe. Knowledge about the comprehensive application is crucial for reaching effective acaricide results of the veterinary medicines and avoiding mite resistance [45]. Surprisingly, about 20% of the beekeepers both in the Americas and in Europe did not treat their colonies at all for varroa, representing a serious risk for bee health and the spread of the parasite to other apiaries.

The majority of beekeepers are interested in additional bee health training and, at the same time, are willing to connect themselves with veterinary experts specialized in bees. It is important to note that, unfortunately, both in Europe and in the Americas, a standardized training program for beekeepers, harmonized across different geographical areas is still missing. In spite of this, significant funds are provided for this goal by the EC.EUROPA.EU (2020–2022) [46], and efforts for education are provided even by other international organizations [20,47].

5. Conclusions

This global online survey enabled us to reach beekeepers in multiple countries in order to assess current demographic trends; summarize the practices used; understand the awareness regarding varroosis and the use of acaricides; and, at the same time, analyze the interest of beekeepers in additional training. The results of our study indicate that the use of a globally distributed survey could be used as an assessment tool on the adoption of GBPs and BMBs in beekeeping. Given that the survey results highlight a huge interest of beekeepers about training in apiculture, this survey could provide useful topics to be implemented during beekeeping programmes to improve the knowledge and awareness of GBPs and BMBs. Further studies should be carried out to understand what main communication channels are adopted by beekeepers around the world in order to gather more answers to the questions asked in this survey, as well as those neglected in order to have a more comprehensive vision of beekeepers' needs.

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Appendix A. Structure of the Questionnaire

Questions gathered into five sections: A (Demographic data), B (Apiary management), C (Varroa knowledge and biosecurity measures adopted), D (Antimicrobial use for varroa control), and E (Training and interest to update).

Question Number	Text	Section
1	In which continent are you located?	A
2	User Language	
3	Year you are born	
4	Mark your gender	
5	Mark your highest education level	
6	How many years have you been a beekeeper?	
7	Do you consider yourself a professional beekeeper?	
8	Estimate the number of hives you are currently managing	B
9	What type of hive are you using?	
10	Do you move your bees at all throughout the year?	
11	How often do you inspect your hives during the active season?	
12	Which of the following photos is an example of varroa mites?	C
13	How knowledgeable are you regarding varroa?	
14	How useful do you think each example below is at varroa prevention/control? [1–8] 1. Adopt/provide hives with screened bottom boards 2. Provide sufficient number of healthy spare bees at the right time 3. Nuclei and swarms should originate from colonies with no clinical signs of diseases related with varroa 4. Treat swarms (no brood) just after harvest 5. Adopt diagnostic tools for measuring varroa infestation levels (for example, icing sugar method, CO_2 test, mite fall etc.) after treatments and during the year (for example, in the spring at the beginning of beekeeping season or before harvesting) 6. Maintain the number of varroa below the harmful threshold in each colony 7. Have good knowledge of the signs of varroosis and virosis 8. Select and breed queens that are more varroa tolerant/resistant	
15	Have you treated your bees with medicine against varroa in the last 2 years?	D
16	List any medicines against varroa you use regularly	
17	Indicate where you get your medicines against varroa that you use	
18	Do you normally need to get a prescription for medicines against varroa?	
19	If/when you use medicines against varroa how do you proceed? [1–7] 1. Treat simultaneously all colonies of the apiary 2. Rotate the products 3. Perform at least 2 treatments per year 4. Monitor efficacy of treatments: detecting high varroa infestation levels by identifying varroa mite presence on adult bees, during hive inspection 5. Use preferably medicines allowed in organic farming 6. Monitor efficacy of treatments: verifying varroa mite presence on adult bees after treatment (e.g., powder sugar, alcohol wash, soapy water) 7. Treat only the diseased hives in an apiary	
20	How often do you think beekeepers use medicines against varroa without following the label instructions?	
21	Would you be interested in bee health training?	E
22	Would you be interested in an online training course?	
23	How interested are you in a nationwide service connecting beekeepers with veterinary experts specialized in bees?	
24	Please, list any bee-specific training or courses that you've attended	
25	Please list any professional beekeeping associations/groups related to bees that you belong to/know about	

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