Food and Agriculture Organization of the United Nations

An international survey comparing antimicrobial resistance risk and awareness between beekeepers in Europe, the United Kingdom and North America

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Food and Agriculture Organization of the United Nations
Rome, 2021

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Executive Summary

The study shows the results of an on-line international survey elaborated as a risk assessment tool concerning the use of antimicrobials and the awareness on antimicrobial resistance among beekeepers. The survey was conducted in collaboration between the Animal Production and Health Division of the Food and Agriculture Organization of the UN (FAO), Appalachian State University (CARE) and the Istituto Zooprofilattico Sperimentale del Lazio e della Toscana (IZSLT). The survey was disseminated for a period of 12 months in ten languages at the global level through the Technologies and Practices for small agricultural producers (TECA) Platform of the Food and Agriculture Organization of the United Nations (FAO), in collaboration with the International Federation of Beekeepers' Association (Apimondia).

A total of 297 responses were received, most of them (49%) from Continental Europe (primarily Italy, Denmark, Belgium and France), northern America (19%) and the UK (32%). More efforts should be done in the future to spread the survey across geographical regions, providing a more active distribution of the survey, with the involvement of additional beekeepers' associations and social platforms.

Concerning antibiotics, the results showed, both in Northern America, UK and Continental Europe, a quite low percentage of beekeepers (2-5%) used them to control the infectious diseases of honey bees. In the European Region, no antibiotics are currently registered for the bees as great efforts are provided to prevent and control infectious honey bee diseases with the application of good beekeeping practices and incineration of the affected hives.

To acquire antibiotics, in the European Region beekeepers passed through pharmacies or inspectors, while, especially in northern America, they used the internet (where prescriptions are unfortunately not always required). Moreover, especially in Northern America, beekeepers reported the failure of treatments for bacterial honey bee diseases (American and European Foulbrood).

In general, the current lack of approved active ingredients to treat nosema was demonstrated by a significant demand (especially in Northern America) for new medications.

Concerning the antimicrobial resistance awareness, specific needs for training were related to:

- the lack of adherence to the label indication (above all in Northern America);
- little knowledge on antimicrobial function and the possibility to find their residues in hive products (above all in European Region).

It seems necessary to ensure beekeepers have access to accurate information, ideally provided by reliable sources and trained experts, on the above mentioned aspects.

Acronyms and Abbreviations

IZSLT = Istituto Zooprofilattico Sperimentale Lazio e Toscana (Experimental Zooprophylactic Institute of Lazio and Tuscany)

TECA FAO = Technologies and Practices for Small Agricultural Producers beekeeping of the Food and Agriculture Organization of the United Nations

1. Introduction

Apis mellifera is one of the most abundant species of pollinators worldwide and a crucial pollinator in crop production (Chauzat et al. 2013; Gallai et al. 2009). Recently, honeybees have been strongly impacted by a variety of recurring and emerging diseases, the spread of which has been furthered by international trade of honeybees and honeybee products (Bacandritos *et al*. 2010). Two prominent diseases recognised by OIE are American Foulbrood and European Foulbrood caused respectively by the bacteria *Paenibacillus larvae* and *Melissococcus plutonius* (Forsgren, 2010). While various control strategies have been implemented, several antibiotic products have been registered for use on honey bees in countries such as the United States of America, China and Canada ("American Foulbrood - Prevention and Management", 2020; "Using Medically Important Antimicrobials in Bees", 2020). Other countries, such as member states of the European Union have introduced policies to actively discourage and limit antibiotic use ("Residues of Veterinary Medicinal Products - Food Safety - European Commission", 2020; Ministero della Salute, 2012; Tierarzneimittelkontrollgesetz Nr. 28/2002).

Nonetheless, multiple studies have reported elevated levels of antibiotic residues in honey samples deriving from countries that do not permit antibiotic use, as well as established resistance to antibiotics frequently used where these medicines are allowed (Galarini et al. 2015; Al-Waili et al. 2012; Reybroek et al. 2012; Reybroek, 2017). These reports suggest a potential for illegal use, gross misuse of antibiotics, and call for a deeper understanding of whether beekeepers are well informed on appropriate antibiotic use. Under the One Health concept, antibiotic misuse in honeybees could have a substantial effect not only on the treated bees, but also on food safety of hive products as well as on the environment concerning the development of antimicrobial resistance (Al-Waili et al. 2012).

A globally distributed survey concerning the use of veterinary medicines in beekeeping was developed through a collaboration between the FAO, Apimondia, Appalachian State University and the Experimental Zooprophylactic Institute of Lazio and Tuscany (IZSLT). This report focuses on the antibiotic resistance (ABR) survey, which was implemented as a risk assessment monitoring current use and awareness of antibiotics and their related risks in beekeeping. Online 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 (Yoshikawa *et al*. 2008). Surveys are also

useful tools to periodically reassess those practices after corrective actions have been put in place. The survey was designed and distributed with the intent of reaching beekeepers globally in order to detail a comprehensive picture of antibiotic practices.

2. Materials and Methods

The survey was administered through Qualtrics and hosted by the U.N. Food and Agriculture Organization website. Qualtrics allows us to capture demographic characteristics. Beekeepers were asked to self-report on their own demographic characteristics and usages of a range of best practices, both general and specific to the survey topic. Access to a computer with an internet connection was required to complete the survey. All responses have been kept anonymous for the safety and protection of the respondent's personal information.

The survey was translated and made available in 10 languages: Arabic, Chinese, Danish, Dutch, English, French, Italian, Russian, Slovenian, and Spanish. The survey took approximately 5 to 10 minutes to complete. The surveys were marketed, in part, by the Center for Analytics Research and Education (C.A.R.E) at Appalachian State University. *HiveTracks* sent a targeted email to over 4,650 people, and Bee Culture Magazine reached an estimated 20,000 readers through advertising. HiveTracks also promoted the surveys to over 2,400 followers on Facebook and 245 users on Twitter. Additional marketing and promotion was provided by Apimondia and TECA partners, including FILAPI, BNNS, and MMH.

The original questionnaire developed by IZSLT in the context of the ‘BPRACTICES’ project (EU ERA-NET Susan project) was broken out into three separate surveys, each administered online via Qualtrics and promoted by multiple affiliated parties including beekeeping associations (APIMONDIA), bee research groups, the U.N. F.A.O., C.A.R.E., and others. The three surveys were grouped in the following categories: Antimicrobial Resistance, Varroa Management, and Infectious Disease Management. Over 1,600 beekeepers from more than 30 countries worldwide responded to the surveys over the course of 12 months (January 2019 - December 2019) prior to the analysis stage. An overwhelming majority of responses across all three surveys came from individuals living in the European Union, North America, or the United Kingdom. Due to this factor, the methodological approach was adjusted to only include respondents from those regions, as there were not enough participants from other regions to have a statistically valid sample to use for analysis.

Each of the three surveys have identical blocks of demographic questions including age, gender, education, and location, as well as general beekeeping practice questions including years of experience, number of hives managed, frequency of hive inspections, types of hives used, and hive movement patterns. The Antimicrobial Resistance survey goes on to measure the respondent's knowledge base and use-level of antibiotics in their beekeeping practice, as well as their experience dealing with antimicrobial-resistance diseases. The Varroa Management survey drills down on the specific application of bee medicines and hive management practices meant to protect against infestations of the destructive parasite, while the Infectious Disease Management survey focuses on the usage and feasibility of preventative practices for controlling the spread of the bacterial infections Nosema, European Foulbrood, and American Foulbrood. While around 25% of participants responded to all three surveys, the rest responded to one or two of the surveys.

Any identifying information such as IP addresses which were collected by Qualtrics were deleted. The levels of measurement for the majority of questions are based on the 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 currently being managed use continuous quantitative measures. All other variables were coded numerically to include a baseline of 0 for the lowest categories (i.e. "none", "no", "never", "disagree", etc.), and increasing to the highest category. The coding scheme also excludes or re-codes statistically meaningless response options (i.e. "i don't know", "neutral", "not applicable", etc.). We used the statistical software program STATA for the analysis.

The primary methodological approach for the statistical analysis utilized mean comparisons between the three key regions of interest: North America, the U.K., and the E.U. Advantages to this method include identifying the areas where statistically significant differences exist between regions across the range of variables measured in each survey. This allows professionals in data analytics to highlight the key discrepancies in apiary management practices between locations, which in turns provides bee entomologists a vantage point from which to focus in on the underlying factors influencing variation across population groups.

Given the largely categorical nature of the data, t-tests were used to compare central tendencies of each region. A minimum significance threshold of $p < 0.1$ was used to assess statistical differences, with E.U. respondents serving as the base group from which to compare U.K. and North American beekeepers. The distribution of responses for each variable were

visualized using box-plot comparisons between regions to show interquartile range, mean/median, and variance. Given the lack of theoretical assumptions in this analysis, two-tailed tests were used throughout.

With the three surveys having been distributed online via the Qualtrics platform, certain compromises had to be made in pursuit of efficiency. Access to a computer with an internet connection is a necessary precondition for participation in this project, which unfortunately limits the ability for beekeepers with limited technological resources to engage with the project. However, the advantages of collecting survey data digitally are numerous, including a significant reduction in the labor-intensive process of collecting, organizing, and cleaning the data, as well as the potential for global outreach to any beekeeper with the ability to connect to the internet. It is important to note that inherent sampling bias is present as a result of the survey delivery platform, but restricting the scope to only include respondents from the E.U., U.K., and North America, where access to computers and internet is prevalent, greatly reduces this issue.

The three surveys were analyzed separately; in this paper, we report the results of the Antimicrobial Resistance Survey (AMR).

In the next section we present the results of the analysis for the AMR Survey focused on mean comparisons between the outlined areas: EU, UK, North America.

3. Results of Data Analysis

A total of 297 (responses were received for the AMR survey, of which 48.8% (n=145) were from continental Europe, 32.3% (n=96) were from the United Kingdom, and 18.9% (n=56) were from North America. The responses received from other geographical areas were not sufficient to be included in a statistical analysis.

Section 1 Overview: Demographic Questions (Q1 – Q11)

The average beekeeper age ranged between 53-62 years of age, with Europe presenting significantly younger beekeepers compared to the UK and North America. Female beekeepers made up the highest percentage in the UK (39%), with no statistical difference noted between the three groups. Average years of experience saw a significant difference between the EU and other regions, with an average of 19 years compared to 14.7 years in the UK and 14.4 in North America. Europe also yielded a significantly higher percentage of professional beekeepers (22%) compared to the UK (7%), as well as the highest number of hives on average per beekeeper (46) compared to the UK (9) and North America (12). Europe additionally had the highest percentage of migratory beekeepers (26%), which was significantly higher than the UK's 12% and 9% in North America. The average number of yearly inspections showed little variation, with North America performing statistically fewer inspections (2.1) compared to the control group, Europe, with (2.5) (See **Table 1).**

Table 1: Demographics/Hive Management Overview

Question	**European Union** *(Avg N= 142)*	**United Kingdom** *(Avg N= 93)*	**North America** *(Avg N=54)*
	Avg/Percent	Avg/Percent	Avg/Percent
Average Age	53	61**	62**
% Female	27%	39%	36%
Average Years Experience	19	14.69**	14.41**
% Professional Beekeepers	22%	7%**	11%
Average Number Hives	46	9**	12**
% Migratory	26%	12%**	9%**
Average Yearly Inspections	2.52	2.56	2.07**

*=p<0.05, ** = p<0.01, Avg N = Response rate varies for these questions by a small percent; average was taken for readability

Beekeepers in the UK had the highest levels of education with 42% having postgraduate qualifications and 27% having a university degree, followed by North America with 34% and 36% respectively (See **Table 2)**.

Table 2: What is your highest completed level of Education?			
	European Union (*N=146)*	**United Kingdom** *(N=96)*	**North America** *(N=56)*
High School or Less	27%	9%**	7%**
Vocational, Technical, Associates, or Some College	21%	22%	23%
University Degree	25%	27%	36%
Post-graduate qualification	27%	42%*	34%
*=p<0.05, ** = p<0.01			

When assessing hives used, the EU mainly used the Dadant Blatt (57%), the UK preferred the British Standard National Hive (75%), a modified Langstroth beehive, and North America relied on the Langstroth (11%) (See **Table 3)**.

Table 3:What types of hives do you use in your apiary? (Check all the apply)			
	European Union *(N=158)*	**United Kingdom** *(N= 100)*	**North America** *(N=57)*
Top-Bar	4%	0%*	2%
Langstroth	4%	2%	11%**
Warre	1%	6%	6%
Dadant Blatt	57%	0%**	0%**
Other: British National	0%	75%**	0%
Other: Simplex	6%	0%	0%
Other	31%	21%**	9%**
*=p<0.05, ** = p<0.01,			

Section 2 Overview: Antibiotics Knowledge and Applications (Q12-Q23)

Respondents from all three areas reported that antibiotics are mainly intended for bacterial control (EU=68%, UK=80%, North America=80%), followed by disease cure (EU=43%, UK=47%, North America=36%). North American beekeepers were more likely than the other regions to indicate that antibiotics were intended for disease prevention (25%)(See **Table 4).**

Table 4: What are antibiotics intended to do?

	European Union *(N=158)*	**United Kingdom** *(N=100)*	**North America** *(N=57)*
Disease Prevention	7%	11%	25%**
Disease Cure	43%	47%	36%
Control Bacterial Infections	68%	80%*	80%
Hive Production	1%	2%*	4%
Other	1%	4%	4%

**=p<0.05, ** = p<0.01*

Beekeepers in the EU were significantly more likely to gain information from a veterinarian (46%) compared to only 16% in the UK and 23% in North America who used this source of information. EU beekeepers were significantly less likely to use a Beekeeper Association (26%) compared to the UK (64%) and North America (60%). Beekeepers from North America were significantly more likely to gain information from the internet (52%) and from Extension Services (40%) compared to the EU (17% and 7%) who used these sources (See **Table 5)**. Notice the high degree of responses in the other category. Most of these respondents indicated that they either did not use antibiotics in their beekeeping or that it was illegal to use them in their country. North America has fewer legal restrictions on antibiotics use than Europe or the UK.

Table 5: Where do you get your information on antibiotics?			
	European Union *(N=46)*	**United Kingdom** *(N= 56)*	**North America** *(N=48)*
Agro Chemical Supply-House	2%	4%	10%
Pharmacy	11%	5%	8%
Veterinarian	46%	16%**	23%*
Other Beekeeper	46%	16%**	23%*
Beekeeper Association	26%	64%**	60%**
Extension Services	7%	4%	40%**
Books	17%	29%	35%*
Internet	17%	30%	52%**
Other	35%	32%	15%
**=p<0.05, ** = p<0.01*			

The EU appeared to be most likely to purchase antibiotics from a veterinarian (11%) or pharmacy (8%), while the US reported using Beekeeper Associations (28%) or the internet (17%) (See **Table 6)**. Those marking the other category here most commonly wrote they got them from the bee supply house, government inspector or did not use them.

The UK reported acquiring antibiotics from National Bee Inspectors. North American beekeepers were significantly more likely to use antibiotics against Nosema infections (14%) and European Foulbrood infections (8%), compared to the EU (3% and 0%) (See **Table 7).** Most of those that marked the other category indicated that they do not use antibiotics.

Table 6: Indicate where you get your antibiotics			
	European Union *(N=37)*	**United Kingdom** *(N=43)*	**North America** *(N=18)*
Agro Chemical Supply-House	5%	0%	11%
Pharmacy	8%	0%	0%
Veterinarian	11%	5%	11%
Other Beekeeper	3%	11%	0%
Beekeeper Association	5%	7%	28%
Extension Services	0%	0%	6%
Internet	3%	2%	17%
Others	73%	86%	53%

Table 7: Do you use antibiotics for any of the following? (Check all that apply)			
	European Union **(***N=92)*	**United Kingdom** *(N= 85)*	**North America** *(N= 49)*
Nosema	3%	1%	14%*
Varroa	4%	4%	4%
American Foulbrood	3%	0%	8%
European Foulbrood	0%	1%	8%*
Other	14%	13%	4%*
**=p<0.05, ** = p<0.01*			

Section 3 Overview: Antimicrobial Resistance (Q23-Q34)

In a self-assessment question regarding antibiotic knowledge, EU beekeepers were more likely to rate themselves as knowledgeable compared to their counterparts in the UK or North America. Thirty-five percent of EU beekeepers rated themselves as "moderately knowledgeable or "extremely knowledgeable," compared to 25 percent in North America and 20 percent in the UK who rated themselves as such.UK beekeepers were most likely to indicated "no knowledge" (35%) or "little knowledge" (32%). In comparison, 18 percent of beekeepers in North America indicated "no knowledge" and 27 percent indicated "little knowledge;" Thirty percent of EU beekeepers reported "no knowledge," and 18 percent assessed themselves as having "some knowledge" (See **Table 8**).

Table 8: How knowledgeable are you in issues of antibiotics intended to be used on bees?

	European Union *(N=125)*	**United Kingdom** *(N=91)*****	**North America** *(N=55)*
No knowledge	30%	35%	18%
Little knowledge	12%	32%	27%
Somewhat knowledgeable	23%	13%	29%
Moderately knowledgeable	22%	14%	18%
Extremely knowledgeable	13%	6%	7%
**=p<0.05, ** = p<0.01*			

EU beekeepers reported the highest level of residue awareness (90%) compared to the UK (80%) and US (84%). UK based beekeepers, however, appeared more aware of drug-resistant infections (98%) compared to beekeepers in the EU (92%) and North America (90%) (See **Table 9** and **Table 10)**.

Table 9: Do you know what antibiotic residues are?

	European Union *(N=127)*	**United Kingdom** *(N=91)*	**North America** *(N=55)*
Yes	90%	80%	84%
No	10%	20%	16%

Table 10: Do you know what drug-resistant infections are?			
	European Union *(N=127)*	**United Kingdom** *(N=92)******	**North America** *(N=55)*
Yes	92%	98%	90%
No	8%	2%	10%
**=p<0.05, ** = p<0.01*			

Antibiotic failure was reported in similar percentages across all three areas, with the EU reporting the highest percentage for never having seen failure (74%). However, when asked about having witnessed resistance to medicines, EU beekeepers had the highest percentages for having seen live examples (11%) and having seen it multiple times (10%) (See **Table 11** and **Table 12)**.

Table 11: How often do you see antibiotics fail to treat bees?			
Ordinal Response	**European Union** *(N=53)*	**United Kingdom** *(N=19)*	**North America** *(N=17)*
Never	74%	63%	47%
Sometimes	17%	32%	35%
Almost always	6%	5%	12%
Always	4%	0%	6%

All three groups indicated believing that beekeepers sometimes use antibiotics without following label instructions (EU=47%, UK=59%, North America=52%), with a large portion of North American beekeepers also believing it happens often (40%) (See **Table 13)**. All three areas similarly reported that recently treated hive products should not be consumed (See **Table 14)**. EU beekeepers were more likely to have been told about the risks of antibiotics by a veterinarian (53%), compared to the UK (38%) and North America (40%) (See **Table 15)**. All three groups mostly reported that drug resistant infections would have a large impact on their lives and businesses (EU=84%, UK=83%, North America=73%), with North America also suggesting a small impact (27%) (See **Table 16)**.

Table 12: Please tell us your experience in recognizing bee resistance to medicines			
	European Union *(N=105)*	**United Kingdom** *(N=85)****	**North America** *(N=55)***
Never seen it	79%	92%	93%
Saw a live example of it	11%	5%	7%
Seen it multiple times	10%	3%	0%
**=p<0.05, ** = p<0.01*			

Table 13: How often do you think Beekeepers use antibiotics without following the label instructions?			
	European Union *(N=101)*	**United Kingdom** *(N=74)**	**North America** *(N=50)*
Never	13%	15%	0%
Sometimes	47%	59%	52%
Often	27%	23%	40%
Usually	10%	1%	6%
Always	3%	1%	2%
**=p<0.05, ** = p<0.01*			

Table 14: Would you agree with the statement that "honey/honeycomb from bees just treated with antibiotics should not be consumed"?			
	European Union *(N=126)*	**United Kingdom** *(N=87)*	**North America** *(N=47)*
Agree	98%	97%	100%
Disagree	2%	3%	0%

Table 15: Has a veterinarian ever told you about the risks of either using medicines too often or the wrong type of antibiotics?			
	European Union *(N=100)*	**United Kingdom** *(N=89)**	**North America** *(N=53)*
Yes	53%	38%	40%
No	47%	62%	60%
**=p<0.05, ** = p<0.01*			

Table 16: How much do you believe drug resistant infections will impact you, your friends and family, and your bees?			
	European Union ***(N=108)***	**United Kingdom** ***(N=84)***	**North America** ***(N=51)***
No Impact	4%	2%	0%
A little impact	12%	14%	27%
A large impact	84%	83%	73%

4. Discussion

Using a global online survey enabled the authors to reach beekeepers in multiple countries in order to assess current demographic trends, practices, and awareness regarding the use of antibiotics and antibiotic associated risks. The survey suggested that age and gender demographics were similar to other reports of beekeeper demographics across multiple countries (Chauzat et al. 2013; Simpach, 2012; Mujuni et al. 2012). It would appear that beekeeping remains an activity where older men are the predominant demographic. In all three areas, beekeeping appeared to be mostly a hobbyist activity for these respondents, with very few beekeepers considering themselves professionals. Future research should actively reach out to professional beekeepers. This finding is relevant in the ongoing effort of the FAO in promoting beekeeping as a viable small-scale business to support rural farmers (Hilmi, Bradbear & Mejia, 2011). It suggests that in these three geographical areas, beekeeping is still mostly viewed as a hobby and perhaps not required as a source of income, however other countries may yield very different responses in future surveys.

Education levels also appeared to vary depending on the geographical region. Notably, many UK hobbyist beekeepers were highly educated, however it is possible that education level influenced respondents' knowledge regarding the issues covered.

Antibiotic knowledge and application was explored through a series of questions that aimed to assess the prevalence of antibiotic use, the prominence of antibiotic intervention, and whether beekeepers have a good understanding of prudent antibiotic use. Beekeepers in all three areas indicated a general appreciation for antibiotic function and intended purposes, with a minor mention of antibiotic use in disease prevention from North American beekeepers. Antibiotics in North America are still largely employed in large production animals as prophylaxis and growth promoters (Landers et al. 2012). These policies are likely to result in fewer efforts to

ameliorate biosecurity measures and antibiotic resistance measures, while promoting the idea that antibiotics can be used to increase production (as indicated by 4% of North American beekeepers) (Sneeringer et al. 2015). It is therefore imperative that beekeepers are properly informed about the risks incurred by antibiotic misuse. In fact, when asked where beekeepers were likely to seek information from, only 46% of European beekeepers relied on veterinarians and were equally likely to ask another beekeeper (46%). In comparison, beekeepers in the UK and North America seemed much more likely to turn to Beekeeper Associations (64% and 60%), but 52% of North American beekeepers also reported relying on the internet. That is not to say that one source of information is less accurate than another, as many veterinarians lack knowledge and expertise with regards to the beekeeping industry. However, trained professionals are much more likely to be able to warn against antimicrobial misuse compared to dated or informal resources that promote antimicrobial intervention (Porter, 2019). The EU was most likely to purchase antibiotics from a veterinarian (11%), while North America relied on Beekeeper Associations (28%) and the internet (17%). The UK adopted a unique position in the matter, relying almost entirely on National Bee Inspectors to provide antibiotics. It is yet unclear which factors influence beekeeper practices in each geographical area, whether legislation, accessibility, or habit. The survey also suggested that North American based beekeepers had the highest reports for antibiotic use, not just against AFB (8%) and EFB (8%), but also against Nosema (14%).

The third section of the survey focused on understanding current awareness of antibiotic resistance and drug-resistant infections, as well as beekeepers' beliefs surrounding these issues. Beekeepers from all three areas indicated having little knowledge regarding antibiotic use in honey bees, with the UK self-reporting the lowest levels of knowledge and the EU self-reporting the highest levels of knowledge. However, when investigating awareness of residues and drug-resistant infection, beekeepers in all three areas reported being informed (80-98% were aware). The survey posed these questions as yes/no questions, however, and did not give respondents the option of rating how knowledgeable they were on each topic, which likely resulted in over-estimation of awareness. The survey further investigated antibiotic resistance by asking about personal experiences in witnessing antibiotic failure and drug resistance. Both questions suggested that between 0-12% of beekeepers from each country have witnessed one of these options. These findings are consistent with studies investigating resistance to

commonly used antimicrobials in beekeeping, and may suggest that antibiotics are either misused for the appropriate disease, or used altogether against the wrong disease, as seen in beekeepers using antibiotics against Nosema. It is not surprising then that most beekeepers believed that antibiotics are sometimes (EU=47%, UK=59%, North America=52%) or often (EU=27%, UK=23%, North America=40%) used without following label instructions. Regardless of beekeeper understanding or use of antibiotics, there appeared to be no difference among the three regions regarding personal beliefs on the impact of drug resistance and the safety of recently treated hive products. Ultimately, the survey was a useful tool in understanding common beliefs, general awareness, and application differences between countries.

The benefits of using an online survey were evident in the number of responses received. The survey revealed itself as a cost-effective tool that could promptly reach beekeepers worldwide, collecting reliable quantitative data. If repeated periodically, the survey could prove to be a simple way of monitoring implemented changes and assess beekeeper practices worldwide, offering insight for targeted actions. The survey also came with some limitations that should be considered in the future. The limited number of languages available meant that many beekeepers had to adapt to versions offered in their non-native language, which may have resulted in language barriers affecting their comprehension and ultimately their answers. Work is already underway to provide additional translations for future versions of the survey in order to minimize the issue. Distribution was also limited to few countries where direct ties to Beekeeper Associations and experts were present; this resulted in large geographic gaps or insufficient responses from certain areas. The outcome of this limitation was the inability to provide a truly global, or more comprehensive picture, as was the aim of the survey. Data analysis was limited to the three areas with the most responses, providing a very narrow perspective of beekeeping practices. This issue has also been addressed by exploring further outreach and sampling strategies. It is possible that elements of bias, such as high levels of education, also influenced the response trends. Perhaps beekeepers holding higher qualifications and degrees are generally more aware of antimicrobial resistance. This also outlines the importance of achieving a more comprehensive view of beekeeping practices, in order to discern if geographical location, level of education, or legislation play a role in beekeeper awareness.

5. Conclusions

The use of a globally distributed survey enabled an in-depth assessment of current beekeeping practices and awareness pertaining to antibiotics and antibiotic related risks. It was concluded that among the three areas investigated, EU, UK, North America, there is a general use of antimicrobials and a basic understanding of antibiotic principles. A few shortfalls were outlined in the appropriate administration of antibiotics, as well as the acquisition of information and products. The results suggest that more efforts are required to educate beekeepers on an international scale in order to ensure in-depth awareness and understanding of antibiotic applications. While the survey allowed an appropriate collection of data from three influential geographical regions, more efforts are needed to obtain data from all countries. The survey is nonetheless a reliable low-cost means that can be used as an international risk assessment tool within the beekeeping industry.

Acknowledgements

Authors thank FAO-TECA beekeeping platform in the person of Charlotte Lietaer for the dissemination of the survey and Riccardo Jannnoni-Sebastianini from APIMONDIA for his precious collaboration and contributions as well as all the beekeepers who took the effort to participate to this survey. Moreover, Authors wish to thank the members of the FAO AMR Inter-departmental Working Group (AMRWG) for contributing to the development of the survey object of this study.