SAKARYA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 e-ISSN 2147-835X Period Bimonthly Founded 1997 Publisher Sakarya University
http://www.saujs.sakarya.edu.tr/

Title: Analysis of Occupational Health and Safety Risks in Beekeeping with FMEA Method

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Recieved: 2022-11-25 00:00:00

Accepted: 2023-02-18 00:00:00

Article Type: Research Article

Volume: 27
Issue: 4
Month: August
Year: 2023
Pages: 708-723

How to cite
Mustafa ÖZDEMİR, Serhan KÖKHAN; (2023), Analysis of Occupational Health and Safety Risks in Beekeeping with FMEA Method. Sakarya University Journal of Science, 27(4), 708-723, DOI: 10.16984/saufenbilder.1228959
Access link
https://dergipark.org.tr/en/pub/saufenbilder/issue/79486/1228959

Sakarya University Journal of Science 27(4), 708-723, 2023

Analysis of Occupational Health and Safety Risks in Beekeeping with FMEA Method

Mustafa ÖZDEMİR [1], Serhan KÖKHAN[*1]

Abstract

Contrary to popular belief, beekeeping, which dates back to prehistoric times and is one of the most important plant and animal production branches today, is not an innocent profession in terms of occupational health and safety. In this study, in order to determine the occupational health and safety risk factors in the beekeeping profession, Interviews with beekeepers were conducted in 10 apiaries operating in Bayburt, where especially wandering beekeeping is practiced. In light of the data obtained from the danger hunt applied by the occupational health and safety specialist, ergonomic, physical, biological, and chemical risks were revealed using the FMEA risk analysis method. The effect, probability, and detection values were found for each failure mode, and then Risk Priority Number values were calculated. As a result of the study, for the five basic stages of beekeeping, 15 processes, 39 failure modes, 72 potential effects, and 39 failure causes were determined. Failure modes with a Risk Priority Number value of 100 and above were evaluated as “situations where urgent action and axiom should be taken,” and preventive axioms were proposed for each relevant failure mode. The number of studies on the risk factors in the beekeeping profession is very limited in the literature. For this reason, it is predicted that this study will fill an important gap in the related field and make significant contributions to the literature.

Keywords: Beekeeping, FMEA, occupational health and safety, risk management

1. INTRODUCTION

Beekeeping is a production activity that includes producing bee products such as honey, royal jelly, bee venom, pollen, and propolis by combining plant resources, bees, and labor, as well as producing queen bees, swarms, and pack bees, which constitute an essential source of income [1]. In Turkey, which is at a high level in terms of natural conditions, it is seen that the profession of beekeeping is carried out quite intensively. This has made Turkey the 3rd in the world with 8,179,000 hives after India and China in terms of the number of hives, according to 2020 data [2]. Although the profession of beekeeping is defined in the "Dangerous" profession class with the code 01.49.01 NACE (EU Economic Activities Nomenclature) according to the Workplace Hazard Classes List published in the Official Gazette dated 27.2.2017 and numbered

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29992, both those who practice this profession and the institutions and organizations that provide beekeeping education do not show sufficient sensitivity about the occupational health and safety risks in the beekeeping profession. Studies on occupational health and safety reveal that occupational accidents, work-related diseases, and occupational diseases can be significantly prevented if conscious, effective, and adequate health and safety measures are taken. In order to prevent or minimize occupational health and safety risks, it is important to control the hazards while they are at the source, to plan the working systems, and to prefer less dangerous processes instead of dangerous ones. In addition, it is necessary to create an occupational health and safety culture by using less dangerous machinery or equipment and personal protective equipment and by adopting occupational health and safety issues by both management and employees [3, 4]. In the studies carried out in this context, it is important to investigate the occupational health and safety risks in the beekeeping profession, defined in the dangerous class, and to determine what precautions should be taken against these risks. In the literature, very few studies examine the beekeeping profession's occupational health and safety risk factors. The information about these studies is presented in Table 1 below.

Table 1 Literature

References	Results
[5]	As a result of the examination of 45 bibliographic sources, it was concluded that beekeepers generally face risks such as mechanical and physical difficulties, environmental and climatic conditions, stress, insomnia, irregular diet, and occupational accidents.
[6]	In the risk analysis made with the FMEA method, especially in terms of food safety, in a honey production unit in Tunisia, it was determined that 56% of the non-compliances were caused by not applying good hygiene and good farming practices.
[7]	In the study conducted with Fine-Kinney Risk Assessment Method on some beekeepers in Turkey, serious chemical, biological, physical, and ergonomic risk factors were determined in beekeepers.
[8]	In the study carried out in Turkey, it was concluded that allergy testing for bee stings is very rare in beekeepers, they stay in tents or barracks, traffic accidents, scorpion, snake bites, tick bites, and fire incidents are common in bee sting transportation, and sometimes bear and pig damages are seen.
[9]	In the study conducted on 3 beekeepers in Australia, it was determined that beekeepers are exposed to ergonomic risks, bee stings, and chemical risks due to heavy loads such as hives.
[10]	In the study on beekeepers' health problems and bee allergy, it was determined that beekeepers have health risks such as bee venom and propolis allergies (including anaphylaxis) and Lyme borreliosis associated with tick bites.

The profession of beekeeping involves significant health and safety risks, and reducing these risks is crucial. However, only considering certain risk factors can lead to ignoring all the other risks and failing to take necessary precautions. Therefore, it is necessary to examine all risk factors in beekeeping and take measures accordingly. This is important not only for the health and safety of beekeepers but also for the sustainability of this profession. Thus, scientific research and studies are needed to consider all risk factors in beekeeping and reduce them.

As far as it has been examined, studies on occupational health and safety risk factors in beekeeping only focus on ergonomics, animal attack, etc. focuses on specific risk factors. In addition, existing risk analysis studies do not offer effective solutions. In this study, all possible risk factors (ergonomic, physical, biological, and chemical) are examined and solutions are offered for permanent and migratory beekeepers.

This study primarily aims to investigate what kind of risks can be associated with beekeeping applications throughout all stages (settlement in the selected apiary, spring maintenance and works, harvest works, autumn maintenance and works, winterization) in terms of occupational health and safety. Subsequently, it seeks to identify the measures that can be taken to minimize these identified risks.

In this respect, it can be said that this study has an original quality.

2. MATERIAL AND METHODS

2.1. Material

This research has been planned as a cross-sectional study to determine the occupational health and safety risks in the beekeeping profession and the urgent and non-urgent measures to be taken against these risks. The materials used in the research consist of the data obtained from the interviews with the beekeepers and the danger hunt applied by the occupational health and safety specialist in 10 apiaries, including the fixed and itinerant beekeepers operating in Bayburt province. The Failure Mode Effects Analysis (FMEA) method was used in the analysis, and studies were carried out to determine occupational health and safety risks in terms of ergonomic, physical, biological, and chemical aspects. Coordinate and map information of the study apiaries are given in Figure 1 and Table 2.

Figure 1 Representation of apiaries included in the study on the map

Bayburt province is among the newly developing regions in beekeeping and according to the data of the Agricultural Economy and Policy Development Institute Tepge Beekeeping 2022 Product Report. There are 75,088 hives in the province, and 500 tons of honey were produced in the same year [2].

Table 2 Coordinate information of apiaries included in the study

Place Names	Coordinates
Akşar	40° 21' 02" N 39° 58' 26" E
Çiğdemtepe	40° 19' 57" N 40° 08' 07" E
Demirözü	40° 09' 43" N 39° 53' 35" E
Kavakyanı	40° 17' 24" N 40° 30' 45" E
Kitre	40° 18' 41" N 39° 51' 55" E
Kop	40° 03' 54" N 40° 26' 14" E
Aslandağı	40° 13' 51" N 40° 13' 48" E
Sırakayalar	40° 05' 51" N 40° 15' 38" E
Taht	40° 17' 18" N 40° 25' 39" E
Yukarı Kırzı	40° 23' 16" N 40° 05' 20" E

2.2. FMEA Method

Reliability is the probability that a component or system will perform its intended function for a specified period of time under specified operating conditions [11]. Reliability analysis also aims to measure and analyze a system to eliminate or reduce its failures, probabilities, and security risk. Commonly used reliability analysis techniques are fault tree analysis (FTA) [12–14], failure mode and effect analysis (FMEA) [15, 16], root cause analysis (RCA) [17, 18], and event tree analysis (ETA) [19, 20]. Unlike other reliability management, FMEA is a proactive method to prevent system failures. Its main purpose is to identify, prioritize and act on known or potential system failure modes before they occur. The FMEA stages are shown in Figure 2 [21, 22].

There are different effect, probability, and detection scales in the literature. The scale values recommended and widely used in the study are in Table 3-5 [23-32].

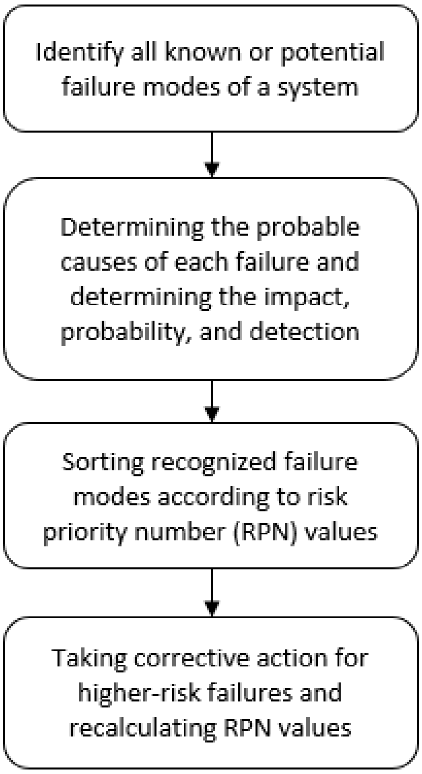

Figure 2 FMEA stages

Table 3 Effect of error mode, intensity of impact, and scale values

Effect (E)	Error Mode	Score
Dangerous without warning	Potential failure mode death without warning	10
Dangerous with warning	Death by warning of a potential failure mode	9
Very high	Serious injury at the disability level	8
High	Incapacity level injury	7
Temperate	Improvement with a break of one month or more	6
Low	Improvement with a one-week break	5
Very low	Improvement with a one-day break	4
Small	Improvement with a short break	3
Very small	Recovery with rapid intervention	2
None	No effect	1

Table 4 Probability expression, number of errors, and scale values of the error mode

Probability of Errors (P)	Error Number	Score
Very High: Failure is almost inevitable	>1 in 2	10
	1 in 3	9
High: Repeated errors	1 in 8	8
	1 in 20	7
	1 in 80	6
Moderate: Occasional errors	1 in 400	5
	1 in 2,000	4
Low: Relatively few errors	1 in 15,000	3
	1 in 150,000	2
Remote: Failure unlikely	<1 in 1,500,000	1

Table 5 Detection of fault mode, detection probability, and scale values by process control

Detection (D)	Detection Probability with Process Control	Score
Absolute Uncertainty	Cannot detect error	10
Very far	It is doubtful that it will detect the error	9
Far	It is unlikely that it will detect the error	8
Very low	Very low chance of detecting the error	7
Low	Low probability of detecting the error	6
Temperate	Medium probability of detecting the error	5
Moderately high	The probability of detecting the error is above medium	4
High	High probability of detecting the error	3
Very high	The probability of detecting the error is very high	2
Almost certain	Detects error	1

While calculating the RPN value, according to Table 3-5, the effect (E), probability (P), and detection (D) values determined by the occupational health and safety experts in line with the data obtained in the face-to-face interviews with the beekeepers are multiplied by each other (RPN = E * P * D). In the evaluation of RPN scores in the study; It has been determined by occupational safety experts that if the RPN score is below 40, there is no need to take any precautions, if $40 \leq \text{RPN} \leq 100$, precautions can be taken, and if it is above 100, it is necessary to take precautions and improve it.

3. RESULTS

In the FMEA tables created in the study, error modes were determined for each process. These error modes were classified in terms of their potential effects, and possible causes of errors were determined. Impact, probability, and detection values were determined for each potential impact in line with expert opinions, and RPN values were calculated. By the determined classification, priority axioms have been determined for error effects with RPN values above 100. In addition to these axioms, In the FMEA tables created in the study, error modes were determined for each process. These error modes were classified in terms of their potential effects, and possible causes of errors were determined. Impact, probability, and detection values were determined for each potential impact in line with expert opinions, and RPN values were calculated. By the determined classification, priority axioms have been determined for error effects with RPN values above 100. In addition to these axioms, axiom suggestions are also presented for all potential error effects with RPN values between 40 and 100. The analyzes made are given in Tables 6-10. Examples of some failure modes identified in FMEA tables before and after improvement are presented in Figure 3-12.

Table 6 Risk assessment reports 1

Stage	Process	Potential Failure Mode	Potential Effect(s) of Failure	Probable Cause(s) of Failure	E	P	D	RPN	Suggested Axioms	After The Axiom			
										E	P	D	RPN
Settlement in the Selected Apiary	Transfer of Hives to the Selected Apiary	Traffic accident	Death	C1	9	3	8	216	A1	9	2	7	126
			Injury		8	3	8	192		8	2	7	112
			Minor Injury		5	3	8	120		5	2	7	70
		Bee sting	Death	C2	9	5	2	90	A2	9	4	2	72
			Loss of Workforce		4	5	2	40		4	4	2	32
	Transport	Incorrect Transport	Short-Term Muscle and Joint Traumas	C3	5	6	5	150	A3	5	4	5	100
			Permanent Muscle and Joint Disorders		7	4	5	140		7	2	5	70
			Injury		5	5	5	125		5	3	5	75
		Trips, Slips, and Falls in the Field	Minor Injury	C4	3	5	5	75	A4	3	4	3	36
			Serious Injury		4	4	5	80		4	3	3	36
			Death		9	3	5	135		9	2	3	54
Spring maintenance and works	Cleaning of Hive Flight Holes, Ventilation	Bee sting	Death	C5	9	6	2	108	A2	9	3	2	54
			Loss of Workforce		4	6	2	48		4	3	2	24
	Nutritional Supplementation If There Is Not Enough Food For Bees	Bee sting	Death	C6	9	6	2	108		9	3	2	54
			Loss of Workforce		4	6	2	48		4	3	2	24
		Fire	Minor Injury	C7	5	4	2	40	A5	5	2	2	20
		Incorrect Transport	Short-Term Muscle and Joint Traumas	C3	5	5	5	125	A6	5	4	5	100
			Permanent Muscle and Joint Discomfort		7	3	5	105		7	2	5	70
	Spraying	Inhalation Poisoning	Loss of Workforce	C8	5	6	6	180	A7	5	4	5	100
		Contact / Skin Poisoning			5	6	6	180		5	4	5	100
		Chemical Burns	Injury and Loss of Work		7	6	3	126		7	4	2	56
		Oral Poisoning	Loss of Workforce	C9	5	5	5	125		5	3	4	60

Table 7 Risk assessment reports 2

Stage	Process	Potential Failure Mode	Potential Effect(s) of Failure	Probable Cause(s) of Failure	E	P	D	RPN	Suggested Axioms	After The Axiom E	After The Axiom P	After The Axiom D	After The Axiom RPN
Harvest works	Honey Harvest	Bee sting	Death	C5	9	6	2	108	A2	9	3	2	54
			Loss of Workforce		4	6	2	48		4	3	2	24
		Incorrect Transport	Short-Term Muscle and Joint Traumas	C3	5	5	5	125	A6	5	4	5	100
			Permanent Muscle and Joint Discomfort		7	3	5	105		7	2	5	70
		Sunburn and Sunstroke	Loss of Workforce	C10	5	5	5	125	A8	5	4	4	80
			Short-Term Loss of Workforce		3	4	5	60		3	3	4	36
		Working in the Sun	Sun Spots on the Skin		3	5	5	75		3	3	5	45
		Non-Ergonomic Working Type	Permanent Muscle and Joint Discomfort (Varicocele etc.)	C11	7	7	6	294	A9	7	4	5	140
		Fire	Loss of Workforce		6	6	3	108	A10	5	5	2	50
	Transport	Incorrect Transport	Short-Term Muscle and Joint Traumas	C3	5	6	5	150	A6	5	4	5	100
			Permanent Muscle and Joint Discomfort		7	4	5	140		7	2	5	70
			Injury		5	5	5	125		5	3	5	75
		Stuck in the Field, Slip, and Fall	Minor Injury	C4	3	5	5	75	A4	3	4	3	36
			Serious Injury		4	4	5	80		4	3	3	36
			Death		9	3	5	135		9	2	3	54
		Unequipped Transport	Hand Cut	C15	5	6	4	120	A11	5	4	4	80
	Honey Straining Process	Improper Honey Harvesting	Hand Cut		5	5	4	100	A12	5	4	4	80
		Strainer Accidents	Injury Due to Entrapment of the Limbs (Hand-Arm) into the Machine	C16	6	6	3	108	A13	6	4	3	72
				C17	6	6	3	108		6	4	3	72
			Injury of Limbs (Hand-Arm) Due to Electric Shock	C18	6	7	3	126	A14	6	5	1	30
	During the Harvest Process	Wild Animal Attack	Death	C19	9	5	6	270	A15	9	3	3	81
			Long-Term Loss of Workforce		6	5	6	180		6	3	3	54
			Short-Term Loss of WorkforcE		5	5	6	150		5	3	3	45

Table 8 Risk assessment reports 3

Stage	Process	Potential Failure Mode	Potential Effect(s) of Failure	Probable Cause(s) of Failure	E	P	D	RPN	Suggested Axioms	After The Axiom E	After The Axiom P	After The Axiom D	After The Axiom RPN
Autumn maintenance and works	Colony Consolidation	Bee sting	Death	C5	9	6	2	108	A2	9	3	2	54
			Loss of Workforce		4	6	2	48		4	3	2	24
		Incorrect Transport	Short-Term Muscle and Joint Traumas	C3	5	5	5	125	A6	5	4	5	100
			Permanent Muscle and Joint Discomfort		7	3	5	105		7	2	5	70
		Bellows Fire	Loss of Workforce	C12	6	6	3	108	A10	5	5	2	50
	General cleaning	Injury	Hand Cut	C13	5	5	4	100	A11	5	4	4	80
		Incorrect Transport	Short-Term Muscle and Joint Traumas	C3	5	5	5	125	A6	5	4	5	100
			Permanent Muscle and Joint Discomfort		7	3	5	105		7	2	5	70
	Disease and Parasite Treatment	Inhalation Poisoning	Loss of Workforce	C8	5	6	6	180	A16	5	4	5	100
		Contact / Skin Poisoning	Loss of Workforce		5	6	6	180		5	4	5	100
		Chemical Burns	Injury and Loss of Workforce		7	6	3	126		7	4	2	56
		Oral Poisoning	Loss of Workforce	C9	5	5	5	125		5	3	4	60
Winterization	Transfer of Hives to the Wintering Site	Traffic accident	Death	C1	9	3	8	216	A1	9	2	7	126
			Injury		8	3	8	192		8	2	7	112
		Hive Fire in Vehicle	Death	C14	9	4	5	180	A17	9	2	5	90
			Injury		8	4	5	160		8	2	5	80
		Bee sting	Death	C2	9	5	2	90	A2	9	4	2	72
			Loss of Workforce		4	5	2	40		4	4	2	32
	Transport	Incorrect Transport	Short-Term Muscle and Joint Traumas	C3	5	6	5	150	A6	5	4	5	100
			Permanent Muscle and Joint Discomfort		7	4	5	140		7	2	5	70
			Injury		5	5	5	125		5	3	5	75
		Stuck in the Field, Slip, and Fall	Minor Injury	C4	3	5	5	75	A18	3	4	3	36
			Serious Injury		4	4	5	80		4	3	3	36
			Death		9	3	5	135		9	2	3	54
	Narrowing the barrel holes	Bee sting	Death	C2	9	5	2	90	A2	9	4	2	72
			Loss of Workforce		4	5	2	40		4	4	2	32

Table 9 Probable cause(s) of failure

Code	Probable Causes
C1	Insomnia, Inattention, Inattention, Fatigue, Rushing, Bee Sting
C2	Bee Sting by a Venom Susceptible Person
C3	Non-Ergonomic Transport Methods, Unsuitable Body Position, and Vehicleless Cargo Transport
C4	Working on Rough Terrain, Carelessness, Insufficient Lighting, Slippery Ground
C5	The sting of a Person Sensitive to Bee Venom by a Bee Due to Not Using Protective Equipment during Cleaning
C6	The sting of a Person Sensitive to Bee Venom by Bee Due to Not Using Protective Equipment during Nutritional Supplementation
C7	Failure to Extinguish the Fire Burned During the Preparation of the Nutritional Supplement (Sherbet) After the Process
C8	Incorrect Spraying, Not Using Personal Protective Equipment (Mask, Gloves, etc.)
C9	Medicated Cake Consumption
C10	Long-Term Unprotected Working in the Sun
C11	Working for a long time while standing
C12	Leaving the bellows used during the honey harvest in the apiary without being extinguished
C13	During the cleaning of the hive, not using a protector and contacting the hand with the cutting metal on the cover
C14	Late Detection of the Fire Caused by the Carriage of the Unextinguished Bellows in the Vehicle and Exposure to the Fire in the Vehicle
C15	Carrying a Hive with One Person, Holding the Hive from Inappropriate Places
C16	Inserting the Limbs into the Machine while the Manual Honey Extractor is Working
C17	Inserting the Limbs into the Machine while the Electric Honey Extractor is Working
C18	Electric Leakage in Electric Honey Extractor
C19	Animal Attack That Comes To Apiary To Meet Its Nutritional Needs (Bear, Pig, etc.)

Table 10 Suggested axioms

Code	Axioms
A1	Should not go out in traffic tired and sleepless. Excessive speed should be avoided. Transportation should not be done during the periods when the bees are actively working.
A2	Bee suits, gloves, etc., and protective equipment should be used. Perfume, etc., that bees will perceive as a threat should not be used. Bananas, etc., should not be eaten, which bees are sensitive fruits. Light-colored clothing should be worn. Sudden and harsh movements should be avoided while cleaning and airing. Allergy medication should be available for reactions that may occur after a bee sting.
A3	Prolonged standing work should not be done. Pay attention to ergonomic carrying positions while carrying loads. If possible, the hives should be carried with two people, or a wheelbarrow should be used.
A4	Care should be taken to choose less rough terrain in selecting an apiary. Before settling in the apiary, a detailed land exploration should be made. An adequate lighting system should be installed. In case of excessive fatigue, transportation should be avoided.
A5	The fire lit to prepare sherbet should be burned in places far from grassy and wooded areas. There is always a fire extinguisher in the apiary, a bucket filled with water, a shovel, etc., for firefighting. Fire equipment must be available.
A6	Do not work standing up for long periods. Attention should be paid to ergonomic carrying positions. Transportation should be done with two people if possible; if not, handcart, etc., tools should be used.
A7	Spraying should not be done without learning the technical spraying methods. Learning the medication dosages Use of personal protective equipment and equipment Paying attention to MSDS labels on drugs
A8	Do not work under the sun for a long time. Hats, scarves, gloves, etc., and, protective equipment should be used. An alternating working system should be established.
A9	Periodic rest breaks should be given while working. An alternating working system should be established.
A10	The bellows used during honey harvest should be burned and extinguished in places far from grassy and wooded areas. There is always a fire extinguisher in the apiary, a bucket filled with water, a shovel, etc., for firefighting. Fire equipment must be available.

Table 10 Suggested axioms (continue)

Code	Axioms
A11	If possible, the hives should be carried by two people. Work gloves should be used in transportation operations.
A12	Work gloves should be used.
A13	The machine should not be intervened before the honey filtering process is completed. A lid system should be installed on the honey extractor, which opens when the filtering process is finished.
A14	The machine should not be intervened before the honey filtering process is completed. A lid system should be installed on the honey extractor, which opens when the filtering process is finished. A leakage current relay should be used.
A15	Electric fence and strobe light should be used. Systems with motion-sensitive sensors should be used. If legal conditions are met, he must have a licensed weapon.
A16	Technical spraying methods should be learned. Education should be given about appropriate periods and appropriate dosages for medication. Personal protective equipment (mask, gloves, etc.) must be used during spraying. The safety information (MSDS) written on the drugs used should be respected.
A17	Do not rush while moving; the bellows should be entirely deflated before putting them in the vehicle. Combustible and combustible materials and bellows should never be placed side by side.
A18	Care should be taken to choose less rough terrain in selecting an apiary. Before settling in the apiary, a detailed land exploration should be made. An adequate lighting system should be installed. In case of excessive fatigue, transportation should be avoided.

Figure 3 Working without gloves

Figure 4 Working with gloves


Figure 5 Unsafe intervention during the honey extraction process


Figure 6 Safe position during the honey extraction process


Figure 7 Improper placement of the bellow


Figure 8 Putting the bellows safely


Figure 9 Incorrect hive handling


Figure 10 Ergonomic hive handling

Figure 11 Sunburn Caused by Working Without Gloves

Figure 12 Working with Gloves Against Sunburn

4. DISCUSSION

This study was conducted to determine the risk factors in occupational health and safety in the beekeeping sector; Face-to-face interviews and in-depth interviews were conducted with the employees of 10 apiaries operating in Bayburt, one of the regions of Turkey with significant potential in beekeeping. Then, with the collected data, occupational health and safety risks related to ergonomic, physical, biological, and chemical factors were analyzed with the FMEA risk analysis method, and axiom plans were created against these risks. It has been predicted that if the axioms recommended for each process with a high-risk value, such as permanent muscle and joint disorders, respiratory, contact poisoning, death, and injury that may occur due to wild animal attack and after beehive fire in the vehicle are implemented, there may be significant decreases in RPN values.

It is thought that the study will fill an essential gap in the literature and will also be a reference study in terms of content and method for future academic and field studies. It is recommended that researchers who will work on a similar subject should consider especially bee breeds, climate, geographical conditions, beekeepers' occupational health and safety awareness level, and cultural codes.

Funding
The authors have no received any financial support for the research, authorship, or publication of this study.

Authors' Contribution
The authors contributed equally to the study.

The Declaration of Conflict of Interest/ Common Interest
No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval
This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics
The authors of the paper declare that they comply with the scientific, ethical, and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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