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Beekeeping Practices and Physicochemical Characteristics of Cameroonian Honey According to the Technological Level

Ngah Osoe Bouli Freddy Patrick[1,2*], Mamoudou Abdoulmoumini[1], Hamidou liman[1], Moffo Frederic[1], Aliou Mohamadou[3] and Wafo Fokam Agnes Jorelle[3]

[1]*Department of Veterinary Medicine, University of Ngaoundere, Ngaoundere, Cameroon*

[2]*Department of Livestock Development, University of Ngaoundere, Ngaoundere, Cameroon*

[3]*Department of Veterinary Science, University of Ngaoundere, Ngaoundere, Cameroon*

Abstract

From January to December 2022 a study was carried out in Cameroon to have a global view of beekeeping practice and the quality of the main product: Honey in relation with technological level. For this purpose, 131 beekeepers were interviewed randomly in the main productive areas of the country and 150 samples analysed. Four physico-chemical variables were studied that is pH, electric conductivity and water content from samples collected at the hive level, at the extraction phase at in the markets. The beekeeping evaluation revealed that the activity is done by young men of 44.73 ± 8.73 years' average, each beekeepers managing around 36.18 ± 20.23 hives with an annual average production of 14.56 ± 11.68 litres per hive. Physicochemical evaluation revealed that almost quarter of the honey samples do not fit the codex Alimentarius standards. pH values were within the normal ranges so as sugars contents and were not influenced by the agroecological origin, but water content and electric conductivity were highly dependent of them ($p<0.0001$). Moreover, the majority of these variables were influenced by the technological level, with the general observation that honeys had poor physicochemical as we go from the hive to the market. This information obtained for the first time in the country reveal a need of sensibilisation program not only for producers and sellers but even for consumers to ensure that the product is not degraded by poor storage condition and beekeeping practices.

Keywords: Cameroon • Beekeeping • Physicochemical characteristics • Agroecological zones

Introduction

Cameroon is a country in the central Africa region that is characterized by a great diversity of ecosystems with up to five (5) agroecological zones [1]. Honey production has a great importance in the agricultural sector of the country, which is the first productive one in the Central Africa Region. However, if beekeeping practices and physicochemical characteristics of honey have been done by previous studies [2], it has been done only in some parts of the country. Moreover, these studies are old and these characteristics not only they have never been studied for the whole country, but they focused mainly on commercial honeys without studying their variation through the transformation chain. Therefore, the aim of this study was therefore to have a general overview of beekeeping practices and the physicochemical characteristics of honey through the chain of transformation. Thus, four mains physicochemical (pH, electric conductivity, total sugars and moisture) were studied respectively on honey collected at the level of the hive, after extraction and from honey collected at the different markets, in order to have a general view of the variation of these variables from the production to the consumer [3].

Materials and Methods

Sample size for beekeeping evaluation

The determination of the sample size of beekeepers has been done through the Thrusfield formula. Since there was no previous study done in the whole country the expected prevalence was set at 10% considering that less than 10% of the population are

***Address for Correspondence:** Ngah Osoe Bouli Freddy Patrick, Department of Veterinary Medicine, University of Ngaoundere, Ngaoundere, Cameroon, Tel: 237679382404; E-mail: ngahosoe@yahoo.com*

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beekeepers with 95% confidence interval and a precision of 5% [4].

$N=Z^2P(1-P)/d^2$

With:

N=Sample size,

Z=Critical value of the normal distribution at the required confidence level (1,96)

p=Sample proportion (0,1),

d=Margin of error or precision (5%)

The size obtained was then allocated proportionally to the production of each region so that the number of beekeepers will reflect the honey weight production per region, while the selection of beekeepers itself was done randomly. The technical characteristics of beekeeping were evaluated via a questionnaire made of 31 questions administered directly to beekeepers.

Sample size for honey physicochemical characteristics

The size of honey samples to be collected was determined by method given by the French Ministry of agriculture for the quality control of honey through the instruction DGAL/SDSPA/2019-94 du 01/02/2019. The size obtained was allocated to the production weight of each region, and samples were collected randomly in the hives, after extraction for the same honey, and in the markets [5].

Moisture (water content) and total sugar evaluation

The moisture content and sugars content were evaluated via the RHB-90 ATC Abbe Refractometer (YHEQUIPMENT CO., LIMITED) equipped with an automatic 20°C corrector for the measurement of the refraction index of the honey. This index was converted to the moisture content in percentage using the Chataway table with Wedmore's corrections while total sugars content was determined via the Brix tables provided by the United States technical procedures manual [6].

pH determination

pH measurements were performed potentiometrically at 20° C using a pH-meter ADWA AD1020 pH/mV/ISE/temperature bench meters-ADWA intruments-Hungary) in a 10% (w/v) solution of honey prepared with CO_2-free distilled water.

Electric conductivity

Electrical Conductivity (EC) was measured on a 20 g/100 g solution of distilled water at 20°C honey solution through a ADWA AD 3000 EC/TDS/temperature bench meter conductimeter (ADWA intruments-Hungary). The instrument was calibrated using standards 1,413 mS/cm, 12,88 mS/cm solutions [7].

Results

Study area and sample size allocation

A total of 131 beekeepers from all the regions in the different areas were surveyed for the evaluation of beekeeping practices and 150 honey samples for the physicochemical evaluation (Figure 1 and Table 1). The study was conducted in three main agroecological areas representing 99.59% of the total honey production estimated at 7205 tons in 2019 [8].

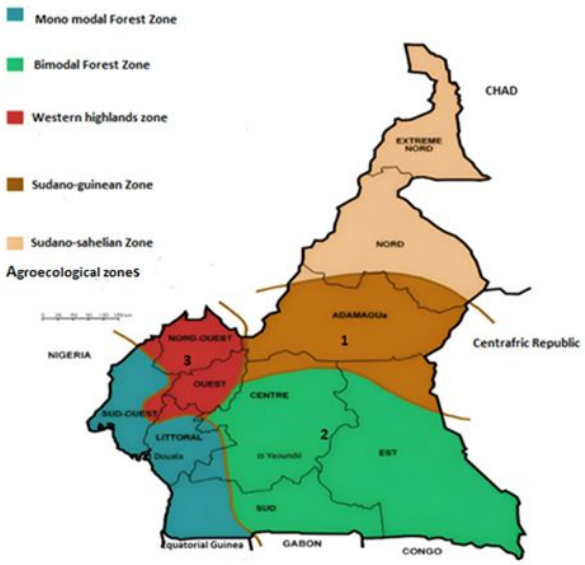

Figure 1. Studied areas.

Agroecological Zones	Bimodal forest	Western highlands	Soudano-guinean	Total
Honey production (2019) in tons	4544	1 655	984	7186
Weigh (%)	63.23	23.03	13.74	100
Sample size allocation for beekeeping evaluation N (%)	84 (64.12)	26 (19.85)	21 (16.03)	131 (100)
Sample size allocation for honey N (%)	90 (60)	30 (20)	30 (20)	150 (100)

Table 1. Honey production and sample size allocation.

Beekeeping characteristics

Cameroonian beekeeping was described as an activity done mainly by men (76 ± 23%) without a significant difference between the areas. Beekeepers for the majority were young, more than the three quarter of them being aged of less than 60 years old with an average age of 44.73 ± 8.73 years old [9].

The type of beehives was significantly different between the areas ($p<0.00001$) conical hives made of straw used essentially in the sudano-guinean agro ecological zone, KTBH and Langstroth with their variants in the western highlands and bimodal forest areas with 37% of beekeepers using in their bee stations at least two types of beehives, essentially KTBH and Langstroth with an average number of 36.18 ± 20.23 hives per beekeeper.

Moreover, Cameroonian beekeeping was characterised with a high productivity ranging from 6.67 ± 4.62 to 20.67 ± 18.58 litres with an average of 14.56 ± 11.68 litres per hive per year with two to four harvest [10].

However, beekeeping technics were poor, the extraction of honey from honeycombs being done traditionally consisting on grinding the honeycombs and filtering through decantation *via* a tissue or a sieve. Similarly, very little beekeepers (14 ± 6.67%) were practicing colonies nourishment, for the sustainment of colonies and baits used were only of two types, honey and wax (Table 2).

Variables	Bimodal forest	Western highlands	Sudano guinean	Frequency (%)	Total	Mean	Standard deviation	Confidence interval	X^2	P-Value
Sex										
Men	60	20	20	76%	100	33.3	23.09	4.53	5.28	0.07
Women	24	6	1	24%	31	10.33	12.1	4.26		
Age										
15-30	12	4	4	15%	20	44.73	8.73	1.5	2.78	0.84
30-45	30	8	4	32%	42					
45-60	24	8	8	31%	40					
60-+	18	6	5	22%	29					
Experience in the activity										
0-5	36	10	6	40%	52	6.28	3.84	0.65	1.46	0.83
5-10	6	2	2	8%	10					
10-+	42	14	13	52%	69					
Number of hives										
0-20	6	2	2	8%	10	36.18	20.23	3.46	0.29	0.99
20-40	6	2	2	8%	10					
40 -	72	22	17	84%	111					
Main challenges										
None	6	2	2	8%	10	3.33	2.31	1.43	5.4	0.71
Diseases	4	2	0	5%	6	2	2	1.6		
Steal	20	8	8	27%	36	12	6.93	2.26		
Firebush	18	6	6	23%	30	10	6.93	2.48		
At least two	36	8	5	37%	49	16.33	17.1	4.79		
Straw hives	0	0	12	9%	12	4	6.93	3.92		
Type of hives										
Kenyan hives	36	10	8	41%	54	18	15.62	4.17	73.27	0.00001*
Hives in frames	12	4	0	12%	16	5.33	6.11	2,99		
>Two types	36	12	1	37%	49	16.33	17.9	5.01		
Number of harvest/year										
0-2	72	22	17	85%	111	37	30.41	5.66	0.3	0.86
2-4	12	4	4	15%	20	6.67	4.62	2.02		
Quantity in liter harvested										
0-50	12	4	4	15%	20	14.56	11.68	2,49	1	0.91
50-100	30	10	9	37%	49					
100-Plus	42	12	8	47%	62					
Way of harvesting										
Traditional	60	18	19	74%	97	32.33	23.97	4.77		

Modern	24	8	2	26%	34	11.33	11.37	3.82	3.56	0.47
Analysis of honey										
Yes	12	4	4	15%	20	6.67	4.62	2.02	0.3	0.86
No	72	22	17	85%	111	37	30.41	5.66		
Baits used										
Honey	6	2	1	7%	9	3	2,65	1.73	0.18	0.99
Wax	78	24	20	93%	122	40.67	32,39	5.75		
Practice of nourishment										
Yes	12	4	4	14%	20	6.67	4.62	2.02	0.29	0.86
No	72	22	17	86%	111	37	30.41	5.66		

Table 2. Beekeeping characteristics in Cameroon.

Physicochemical characteristics

the physicochemical characteristics of Cameroonian honeys from the three main productive areas as presented in Table 3 below, showed important features regarding the four main criteria of evaluation selected [11].

For the pH, the values obtained were in general within the Codex Alimentarius range (3.-6.1). In General, the pH value of honey determines its microbiological stability with the potential to inhibit the growth of pathogens. However, the samples obtained directly during the extraction phase showed high values of pH (4.20 ± 0.01). The electric conductivity gave high values for samples collected directly from the hive while it was in general lower for the samples collected from the markets.

Honeys from the bimodal forest had values above the 800 µs/cm at the harvest, this value decreasing according to the transformational level. The honeys from the sudano-guinean area were in general higher than 800 µS/cm but decreasing from the hive to the market.

Water content characteristics were below the maximum acceptable level (20%) only for samples extracted directly from hives. And increase of its value was observed with the highest for commercialised honey 20.86 ± 1.34% [12].

Sugar content were also within the normal ranges (65-88%) with however the observation than its value was higher for commercialised honeys followed by extracted one,honeycombs analysed having the lowest sugar content value (74.69 ± 6.94 %) [13].

Technological level	Variables	Bimodal forest	Western highlands	Sudano-guinean	Mean	Standard deviation	Confidence interval
		Mean values					
Hive level	pH	4.18	4.03	4.27	4.16	0.12	0.03
	Electric conductivity (µS/cm)	803.66	563.8	953.1	773.52	196.39	40.57
	Sugar content (°Brix)	78.18	66.7	79.2	74.69	6.94	1.43
	Water content	19.86	19.4	19.53	19.6	0.24	0.05
Extraction	pH	4.2	4.19	4.21	4.2	0.01	0
	Electric conductivity (µS/cm)	703.77	735.1	888.9	775.92	99.09	35.46
	Sugar content (°Brix)	77.79	70.3	78.35	75.48	4.49	1.61
	Water content	20.39	19.66	20.72	20.26	0.54	0.19
Markets level	pH	4.2	4.09	4.21	4.17	0.07	0.02
	Electric conductivity (µS/cm)	720.07	687.3	844.4	750.59	82.88	29.66
	Sugar content (°Brix)	79.99	77.13	78.6	78.57	1.43	0.51
	Water content	19.31	21.66	21.61	20.86	1.34	0.48

Table 3. General physicochemical features of Cameroonian honey.

In a more detailed way, the analysis of the physicochemical characteristics showed that 24.81% of honey had at least one parameter that was out of the international norms (Table 4). More precisely only 63.34 ± 11.68% of honey of the Sudano-guinean area, 81.67 ± 18.21% of those of the western highlands and 80.55 ± 8.47% of the bimodal forest fit the international values. Water content was the parameter that showed the highest level of non-conformities among the areas with more than 50% of honeys with a water content above 20%. The influence of the technological level was demonstrated for the electric conductivity and water content in all the three areas with a very significant difference between the different products ($p<00001$). Only sugar content and pH were similar between the areas and among the different transformation

levels. In general, we observed a degradation of the different physicochemical characteristics of the honey from the hive to the market [14].

	pH ≤ 4,5				Electric conductivity ≤ 800 µs/cm				Sugar content (65-88 Brix)				Water content ≤ 20%			
	H	E	Mt	M ± SD	H	E	Mt	M ± SD	H	E	Mt	M ± SD	H	E	Mt	M ± SD
Bimodal forest	100^{a}	93.33^{a}	96.67^{a}	96.67 ± 3.34	100^{a*}	73,33a*	73,33^{a}	68.89 ± 7.7	100^{a}	100^{a}	93.33^{a}	97.78 ± 3.85	53.30^{a}	43.33^{a}	80^{b}	58.87 ± 18.97
Western highlands	100^{a}	100^{a}	90^{a}	96.67 ± 5.77	100^{a*}	60b	70^{b}	76.67 ± 20.82	100^{a}	100^{a}	90^{a}	96.67± 5.77	80^{a}	80^{a}	10^{b}	56.67 ± 40.41
Sudano-guinean	100^{a}	100^{a}	90^{a}	96.67 ± 5.77	10^{a*}	30a*	40^{a}	26.67 ± 15.28	100^{a}	100^{a}	100^{a}	100 ± 0	60^{a}	20^{ab}	10^{b}	30 ± 26.46
M±SD	100 ± 0.00	97.77 ± 3.85	92.22 ± 3.85	96.67 ± 4.01	56.67 ± 45.09	54.44 ± 22.19	61.11 ± 18.36	57.41 ± 3.39	100 ± 0.00	100 ± 0.00	94.44 ± 5.09	98.15 ± 3.21	64.44 ± 13.88	47.78 ± 30.25	33.33 ± 40.41	48.52 ± 15.57
p-value	0.96				0.00001^{o}			0.98				0.00001^{o}				

Note: H: Hive level; E: after Extraction; Mt=Market level; M ± SD=Mean ± Standard deviation.

Values in the lines with different letters are significantly different ($p<0.05$).

Value in column with *are significantly different.

^{o}: p-value is significantly different ($p<0.05$).

Table 4. Proportion of conformities of physicochemical to international standards.

Discussion

Beekeeping characteristics

In this study we aimed to have a general view of beekeeping and physicochemical features of Cameroonian honey in order to assess its level of conformity and security for the consumers [15].

Our study showed that in all areas the activity is done in majority by men such as in eastern Ethiopia as demonstrated by Serda, et al. However unlikely to this study, our results revealed that there is very little investment in equipment as the extraction of is mainly done manually. This can be explained by the lack of the organisation of the activity with the absence of specialised shop for apiculture and also governmental support for the modernisation of the activity [16].

The technical features of beekeeping in Cameroon in general is very similar between the different areas, the only significant difference seen was on the type of beehives [17]. This can be explained by the fact that beekeepers use the local material for the construction of their beehives in order to reduce the cost, while the practice itself is similar. This result is very similar to the results found in other studies in the country by Tchoumboue et al. where the hives were made of clay and bamboo available in the area. Similarly, the type of hives described in other studies general show a link between the local resource between and the fabrication of apiaries like in Ethiopia Gratzer et al., and other eastern countries like Malawi and Uganda [18].

The activity can thus be described as done by experienced young men, with a great productivity but traditionally with little modern equipment. The physicochemical characteristics analysis of the Cameroonian honey revealed that it is almost at 50% of nectar origin and a mixture of nectar and honeydew according to the values of electric conductivity origin and pH [19]. Moreover, these results as they are linked to the agroecological zone, can lead with further studies to geographical certification of these honeys [20].

However, the degradation of physicochemical parameters of honey in relation with the technological level can be explained firstly by the lack of modern equipment for the extraction which can lead in the degradation of the quality of the honey. Secondly there is a possibility of adulteration at the level of market which can justify the fact that the value of differents parameters were the worst at that level as also found by Aykas. The higher level of sugar content at the level of market can indicate the addition of sugar as the main criteria is the sucrose which should not be higher than 5/100 g in genuine honey [21]. However the storage conditions can also explain these changes which were important in water content. The hygroscopic property of honey and lack of appropriate material for honey packaging can lead to higher moisture in commercialised honey.

The high values of water content have been found in previous studies in the Sudano-guinean area, 94,30% of honey having more than 20% of moisture content [22]. This suggest that honeys are harvested before its maturation when water level are low. The specificity of commercialised honey with higher water content and other value outside of the standard range have also been found in Benin Djossou et al., and in Algeria [23].

Thus it is very important to sensitize honey producers and sellers and train them in good beekeeping practices in order to avoid the degradation of honey physicochemical properties which are the first barriers to pathogen contamination and proliferation.

Conclusion

A general view of the beekeeping characteristics and physico-chemical of cameroonian honeys aimed by this study gives important information not only on the practice of apiculture, its challenges but also its potential. There is a need in the production area to modernise the sector and to equip producers with appropriate knowledge through trainings and equipments to boost the production and ensure good beekeeping practices from the hive to the bottle. Specialised packaging and storage conditions should also be given to sellers to ensure the longevity of the product without reducing its quality. Further studies should also be done in the sector especially on the adulterations aspect to ensure the competitiveness of the product.

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Authors' Contributions

Dr Ngah Osoe Bouli Freddy Patrick Conceived and conducted the study, Professors Mamoudou Abdoulmoumini and Aliou Mohamadou supervised the study, Dr Moffo Freddy and Dr Wafo Fokam Agnes Jorelle did the revision of the manuscript, and Dr HAMIDOU Liman did a part of the analysis.

Authors Declarations

Not applicable, the study didn't have any fundings and was financed by personal resources.

Conflict of Interest

We declare that we have no any financial or personal interest that inappropriately influences in writing this article.

Ethics Approval

Not applicable.

Consent to Participate

All the participants gave freely their consent to participate to this study.

Consent for publication

Not applicable.

Availability of Data and Material

Data are available and will be provided if required or asked.

Code Availability

Not applicable.

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