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Quality evaluation of Virgin Coconut Oil processing in Pacific Island Countries using Analytic Hierarchy Process

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Abstract

Edible cooking oil is an integral part of any meal, available in various types and forms in the market. Virgin Coconut Oil (VCO) is one of them and has been found to have many health benefits when consumed adequately. There are various methods have been adopted in the production of VCO based on available technology, which in return affects the yield, quality, and safety of the products produced. Twelve VCO samples from their respective processors were replicated and sent to three separate laboratories for sensory, chemical, microbial, and contaminants analyses to determine their quality and safety. The selection of the best quality and safety of VCO is produced by twelve processors using a hierarchy for an analytical hierarchy process (AHP) that uses the Asian and Pacific Coconut Community (APCC) values as standards. Subjective and objective assessment measures are developed in this new methodology for testing the quality of the best VCO. The quality of twelve VCO producers in the Pacific region is assessed and compared in four categories: sensory attributes, food safety, composition and quality factors, and free fatty acids based on the APCC standards. The evaluation involves assigning individual ranks to each producer as weights in the decision-making process according to their importance to the four categories. Analytic Hierarchy Process (AHP) is employed to facilitate the decision to select the best VCO for the multi-criteria decision-making problem. The methodology could benefit VCO selectors, buyers, and consumers to make the right choices. Quality VCO producers could use this strategy for marketing, and the other producers could look for ways to improve their products.

Keywords: AHP, VCO, APCC standands

1. Introduction

Edible fats and oil is an integral part of any food preparation, cooking and in the meals. Fiji's most readily available edible oil types are soybean oil, sunflower oil, canola oil, corn oil, olive oil, extra virgin oil, mustard oil, coconut oil, and virgin coconut oil (VCO). Edible oil is composed of fatty acids such as polyunsaturated, monounsaturated, and saturated fatty acids. Coconut oils including VCO have high saturated fatty acid content, contributing to its stability during storage and when used in as frying medium (Hamsi et al., 2015). Coconut oil can also substitute palm kernel oil since they both can make up the 'lauric acid oil' sub-complex. Compared to RBD coconut oil, VCO is healthier because it is obtained without heat and chemicals (Hamsi et al., 2015).

VCO production has shown dramatic growth in the market (Bawalan and Chapman, 2006). As a functional food, VCO has been claimed to have numerous beneficial health effects due to medium-chain fatty acid directly absorbed by the intestine and sent to the liver to be used as an energy source (Boemeke et al., 2015). As a result, this reduces the fat disposition in other organs. Studies show that the presence of flavonoids and polyphenols in VCO improves the oxidative stress involved in the etiology of various diseases such as type-2 diabetes mellitus, cardiovascular disease (CVD), and cancer (Boemeke et al., 2015). CVD and diabetes are responsible for a significant proportion of deaths in Fiji, where about 70% of adult men and 75% of adult women are overweight or obese. Specifically, CVD causes one-third of all deaths, while one-quarter of deaths result from diabetes (Shahid et al., 2021). VCO has a higher content of lauric acid and lactic acid bacteria compared to RBD coconut oil and palm oil. The lactic acid bacteria has the ability to kill pathogens, which characterizes VCO as antimicrobial oil, in contrast to RBD coconut oil and palm oil (Suryani et al., 2020). A comparative study of VCO with copra oil (CO), olive oil (OO) and sunflower oil (SFO) on endogenous antioxidant status and paraoxonase 1 activity in improving the oxidative stress in rats revealed that dietary VCO improved the antioxidant status compared to other three oils (Suryani et al., 2020). Supporting the trend, celebrity endorsements have claimed that it helps lose belly fat, curb appetite, strengthen the immune system, and prevent heart disease, dementia, and Alzheimer's disease (Harvard T.H. Chan School of Public Health, 2021).

One of the challenges of coconut oil and VCO production is strenuous manual labor related to coconut climbers and coconut scrappers (Megalingam et al., 2017; Dubey et al., 2016). There is a shortage of coconut tree climbers who can climb and harvest the coconut because harvesting coconut is a dangerous, laborious and challenging task that can lead to serious accidents. This challenge could be overcome by using climbing robots (Megalingam et al., 2017). In 2016 a coconut tree climbing robot prototype was successfully released in India (Dubey et al., 2016). Fiji has the opportunity to implement such innovations, which can help improve the production of VCO and at least meet the local market demands. Scrapping coconuts using a scraper is the second problem in producing VCO since it is time-consuming and laborious. A fully automated machine in South Africa had been designed to reduce both these problems (Mendes et al., 2020). Utilizing robots and automation at the different stages of VCO production may lead to greater yield and less human dependency, and producers will maximize the profits. For instance, a swarm of cooperative unmanned ground or aerial vehicles such as the mechanical system in (Kumar et al., 2015; Kumar et al., 2015, 2016, 2020) could be used in the monitoring of large coconut farms and identifying mature coconuts, robotic arms (such as the mechanical system in (Sharma et al., 2011, 2012) could be used for pick and place of coconuts during the scrapping process, automated articulated mobile manipulators (such as the mechanical system in (Prasad et al., 2022) could be used for harvesting coconuts and then placing them in automated vehicles (Prasad et al., 2020) for cartage and anchored arms can help in the assembly line for labelling and bottling of VCO. All-in-all, the complete process can be automated using automated robots.

There are various VCO products and many producers and manufactures of VCO that sell VCO in the market, and it is difficult for the consumers to determine which one is the safer and healthier product. The integration of ICT in making informed and better decisions is essential to streamline the distribution and marketing of virgin coconut oil, improving efficiency, reducing costs, and increasing profitability (Chand et al., 2021).To make informed selections given different criteria of the products/ services in question, multiple-criteria decision-making (MCDM) or multiple-criteria decision analysis (MCDA) is carried out. MCDA methodology is a non-linear recursive procedure made up of four steps: (i) constructing the decision problem, (ii) articulating and modeling the preferences, (iii) aggregating the alternative evaluations (preferences), and (iv) making recommendations. There are many MCDM methods developed and utilized for countless problem types. The first method, Aggregated indices randomization method, was developed in 1908. Subsequently the method has been modified and improved by a number of researchers around the globe. Other methods include the: analytic hierarchy process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and the Serbian "VIekriterijumsko KOmpromisno Rangiranje (VIKOR)" method, weighted product model (WPM), which were developed towards the end of the century.

This paper compares the quality of VCO produced by twelve selected producers from Fiji, Papua New Guinea, Solomon, and Tonga, whose identities are kept confidential in the Pacific region. The comparison is based on the Asian and Pacific Coconut Community (APCC) VCO standards related to sensory parameters such as color, odour, and taste), free fatty acid composition, peroxide value, and total plate count. The peroxide value gives evidence of rancidity in unsaturated fats and oils, whereas the plate count defines how many aerobic microorganism colonies such as bacteria, yeast, and mould fungi will grow in a controlled environment (Dayrit et al., 2007). The peroxide value and the total plate count help determine the shelf life of the VCO brands. The safety attributes are allocated different weights according to their importance to safety. Analytic Hierarchy Process (AHP) is employed to facilitate the decision to select the best VCO for this multi-criteria decision-making problem. The significant contributions of this paper are:

1. a hierarchy for AHP based onthe safety attributes of APCC for determining the quality of VCO,
2. Creation of both subjective and objective evaluation measures for checking the quality of VCO, and
3. The determination of the contribution of different factors, according to their weights, towards the final decision in choosing the best VCO for use.

In Section 2, a brief background on VCO is presented. The methodology related to VCO samples and their sensory, chemical, microbial and contaminant determination as well as the use of that is the AHP and AHP model is discussed in Section 3. In Section 4, the results are presented, while Section 5 gives a brief discussion on the research findings. In Section 6 the research is concluded with a mention of possible future undertakings.

2. Background

Coconut (Coco Nucifera L) has been an integral part of people's diets and livelihood in the tropical countries of Asia,the Pacific, and parts of Africa for thousands of years (Bawalan and Chapman, 2006). Dubbed the "tree of life" it provides nourishment, oil, cosmetics, medication and shelter materials. Desiccated coconut, coconut milk/cream in liquid form, is the most edible form of the coconut and used frequently in cooking of various dishes. Its meat is very nutritious, packed with dietary fiber, protein, carbohydrates, minerals such as potassium and phosphorous, and vitamins such as niacin and riboflavin (Bawalan and Chapman, 2006).

Coconut oil is extensively used in food preparation, cooking and for industrial purposes. It is rich in medium chain fatty acids (MCFA) and is believed to exhibit good digestibility compared to long chain fatty acids (LCFA). There are two types of coconut oil depending on the extraction methods used; generally, either refined bleached deodorized (RBD) and dry or wet processing. Both have similar fatty acids and triglycerides profiles. However, wet processed oil are observed to have a higher content of bioactive compounds such as vitamin E, sterols, and polyphenols as refining removes a portion of these compounds (Marina et al., 2009a).

Refined Bleached Deodorized (RBD) coconut oil that is brown in colour is commonly produced from copra through high temperature dry processing method (Marina et al., 2009b; Ngadirana et al.). Heat is applied during deodorization process which is carried out at very high temperature. VCO is the second type of coconut oil that does not go through the RBD process. It is extracting the cream from fresh, mature kernel by mechanical or natural means with or without the application of heat, and without chemical refining, which consequently breaks the cream emulsion and releases the oil and that retains its natural state without any alteration (Marina et al., 2009b). This method preserves the sensory and functional properties of fresh coconut, where the resulting oil is pure, clear, colorless, with a scent of fresh coconut now marketed as functional oil, targeted mainly for cooking. Because VCO is, not refined and has no additives added, is safe for human use in its natural condition.

The consistency and quantity of VCO collected are directly influenced by the extraction method used. Apparently, in the Pacific Island region, VCO processing is determined by the types of technology available and are generally categorized into two; fresh-dry processes and fresh-wet processes (Bawalan, 2011). The fresh-dry processing VCO is obtained directly from fresh coconut kernels that are heated mechanically to a temperature of 700C° for a certain duration until it achieves at least 10-20moisture content prior to extraction of VCO with the use of either low pressure oil extraction method, high pressure expeller method or fresh-dry centrifuge method. A general fresh-dry extraction method flow chart in shown in Figure 1.

In the Pacific region, low pressure and high pressure expeller methods as shown in Figure 1, are mainly practiced. For example, the fresh-dry low pressure oil extraction method that uses the direct micro expelling (DME) technology having a flat-bed conduction type dryer is commonly used in Fiji, Federated States of Micronesia, Papua New Guinea, Solomon Islands and Samoa (Bawalan, 2011). VCO produced from DME method is less viscous with less intense coconut aroma due to low pressure extraction, where not all natural gums in the coconut kernel are extracted with the oil. The fresh-dry high pressure expeller method used in the Pacific region uses the Tiny Tech Machine for extracting oil after the ground white coconut kernel is dried to a moisture content of 2.5−3 with the use of a conveyor type hot air dryer. VCO produced using this high pressure expeller is viscous and feels a little greasy with moderate intense coconut aroma due to the extraction of all the natural gums present in the fresh kernel to the oil.

Fresh-wet processing method of producing VCO involves recovering the oil from coconut milk either by heating or non-heating procedures. The wet process is shown in Figure 2. There are generally three fresh-wet extraction methods of producing VCO. These include the modified kitchen method, modified natural fermentation method and the fresh-wet centrifuge method (Bawalan, 2011). These methods require the fresh kernel to be grated with comminuted and prior to extracting the milk with or without the addition of water. The extraction of milk is usually done manually or with the use of horizontal type press milk extractor. The yield and quality of coconut milk obtained from a batch of fresh coconuts depends on the following factors; coconut variety, nut maturity, particle size of kernel and kernel temperature prior to extraction, ratio of water to comminuted kernel (if water is added) and the extraction pressure. VCO produced from the fresh-wet process has very light texture, much like mineral oil, and is easily absorbed by the skin. This is actually the major advantage of VCO produced from the fresh-wet process over VCO produced from the fresh-dry process. The natural gums in fresh coconut kernel are extracted together with the coconut milk. However, these gums are automatically removed when VCO is recovered from coconut milk by other methods. Oil is extracted through coconut milk by heating process while non-heating process, the oil is extracted through an aqueous extraction process either through fermentation process, supercritical fluid extraction process, or enzymatic extraction process. The oil extracted without heating is found to be excellent compared to the heating process of oil extraction in retaining the functional characteristics of fresh coconut.

As a plant product, coconut oil contains biologically active substances that provide nutraceutical/health

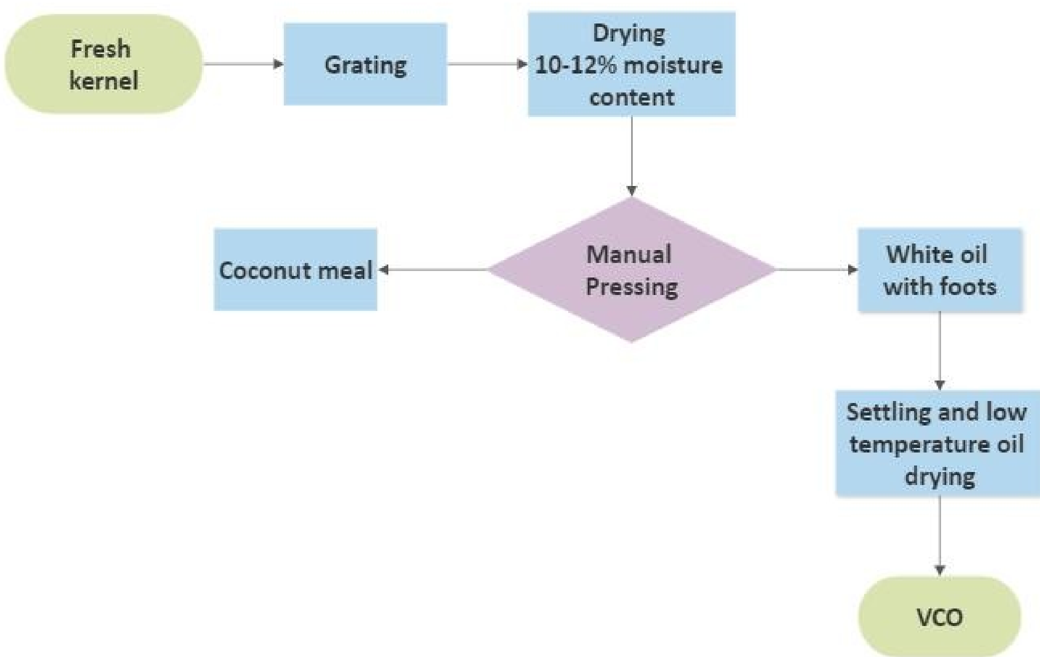

Figure 1. Fresh-dry processing method for VCO.

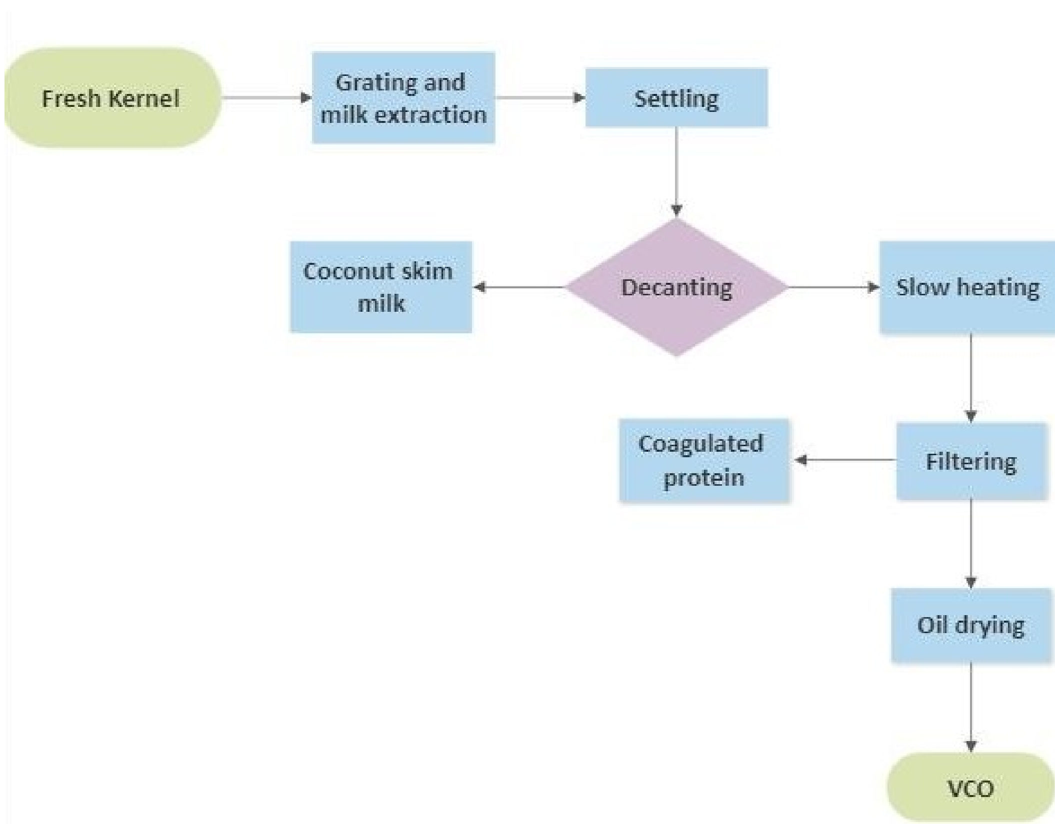

Figure 2. Fresh-wet processing method for VCO.

benefits. Apart from food, VCO has the potential to be established as a carrier for drug preparations, including penetration enhancement, due to its high content of fatty acids (especially lauric and oleic acid). VCO is also effective and safe to be used as a moisturizer on the skin, improving skin hydration and speeding up skin healing (Noora et al., 2013; Varma et al., 2019).

Although studies may take years to probe the pharmacological effects of these substances, there is growing interest worldwide in the role of these biologically active substances in human health. Tocopherols, which are already known as antioxidants, have a role in preventing certain chronic diseases like coronary heart disease and cancer. Tocotrienols is said to be better antioxidants than tocopherols and are effective in treating many diseases (Sen et al., 2007). Phytosterols have been known to lower blood cholesterol, specifically (Salehi et al., 2020).

Various trials have been performed in order to determine the health benefits of VCO. The use of VCO in the diet has been showing to improve biochemical derangements linked to cardiovascular disease (CVD), thus lowering CVD risk (Ma and Lee, 2016). Blood pressure, blood sugar, and obesity are only a handful of the significant health challenges people face, and VCO has proven to help with these issues (Srivastava et al., 2018). However, the majority of these experiments were conducted on primates, with only little human evidence (Ma and Lee, 2016). In human intervention studies, more research into the health benefits of VCO is required. The VCO's effectiveness does not end there. Vaginal candidiasis and vaginal discharge can also be treated with VCO (Winarsi et al., 2008). A decrease in bacterial growth was also followed by decreased vaginal secretion pH.

With the dawn of the energy crisis the globe is facing, the latest fuel industry developments are coconut oil-derived esters used as a diesel fuel substitute. The Philippines use VCO as a fuel additive for diesel (up to 5% blend) to support the Clean Air Act of the country (Bawalan and Chapman, 2006). In the Pacific, countries like Fiji and the Solomon have also introduced Diesel-VCO blends with successful trials in government vehicles in Fiji already bearing fruit (Singh, 2010) .

3. Methodology

A total of twelve VCO processors from four Pacific Island countries VCO were sampled for analyses. The processors were selected based on the VCO processing methods they used, either dry or wet methods. Out of the twelve processors selected, seven VCO samples that used dry methods and five VCO samples that used wet methods were selected. VCO samples were sent to three separate laboratories for sensory, chemical, microbial and contaminant analyses. The sensory evaluation included color, aroma and taste, while the chemical analyses included relative density, refractive index at $400°C$, % moisture, % insoluble impurities, saponification value, iodine value, % unsaponifiable matter, specific gravity at $300°C$, acid value, peroxide value, fatty acid compositions, lauric acid and peroxide value. Microbial load was determined using total plate count and contaminants analyses included matter volatile at $105°C$, iron, copper, lead and arsenic levels. The analyses conducted at the three laboratories adopted either the American Oil Chemist Society (AOCS) https://www.aocs.org/attain-lab-services/methods/methods/search) or Association of Analytical Chemist (AOAC, 2005) procedures respectively.

3.1. Analytic Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a decision-aiding method developed by Saaty (Saaty, 1984, 2001). It aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of the decision-maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of alternatives in the decision-making process (Saaty, 1984). AHP is commonly used in product selection, as it allows companies and consumers to compare products and services against each other in terms of features, cost, performance, etc., and then make an informed decision about which product or service best meets their needs. The process can be applied to any type of product selection process including consumer goods, industrial products, services, software programs, and so on. The AHP method helps in promptly identifying the most suitable option for their needs without having to undertake lengthy research or comparison processes.

AHP requires the decomposition of a goal into a homogenous set of dimensions (sub-goals or criteria). Each dimension can be further divided into sub-dimensions to develop an analytical hierarchy. In this study, the overall quality of twelve VCO producers in the Pacific was ranked and compared by firstly, determining the individual ranks and then subsequently the best overall VCO producer in each of the following categories;

- sensory attributes,
- food safety,
- composition and quality factors, and finally its
- free fatty acids.

Pairwise comparisons of dimensions based on four attributes of VCO produced from 12 different companies namely $P1, P2, P3, ..., P12$ was prepared and relative importance was rated in each hierarchical path to determine the relative priority weights for each dimension. These four categories were Identity Composition and Quality Factors, GLC Range of Fatty Acid Composition (%), Sensory characteristics and food Safety characteristics. The twelve VCO products were ranked in these 4 different categories, and then finally, the overall best VCO producer was found by analysing these four categories together

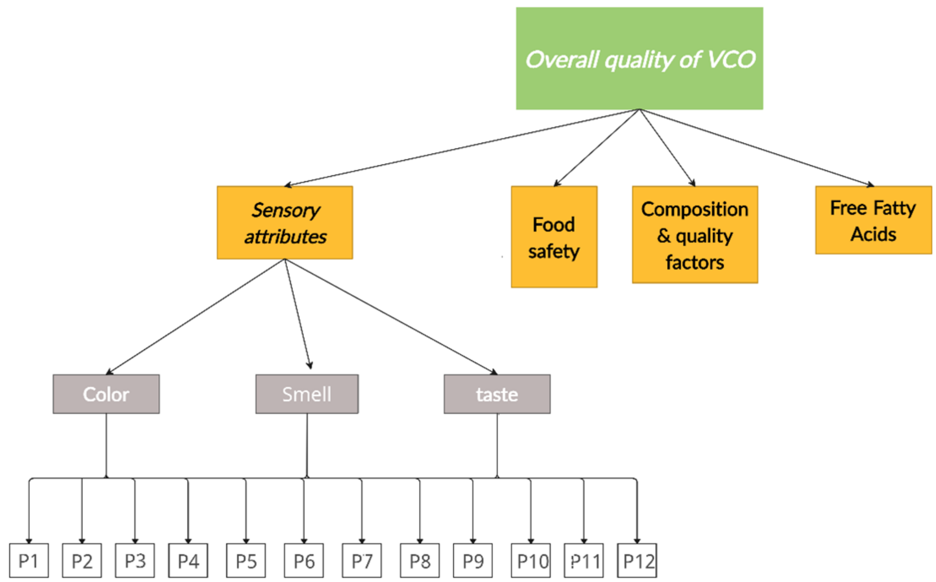

Figure 3. The multi-layer AHP hierarchy, fully expanded for the 1st category.

using AHP.

The subcategories for the "sensory attributes" are color, smell and taste as shown in Figure 3. The second category "food safety" was divided into six subsections. These are the matter volatile at 105 degrees, Iron, Copper, lead, Arsenic levels and the total plate count. The "composition and quality" category was divided into several subdivisions such as relative density, refractive index at 40 degrees, percentage moisture, insoluble impurities percentage, saponification value, iodine value, unsaponification matter percentage, specific gravity at 30 degrees, free fatty acids as oceic, and the peroxide value. The monounsaturated, polyunsaturated, and saturated fatty acids from C6:0 to C24:1 made up the last category free fatty acids (FFA).

Furthermore, consistency tests for the AHP method are performed to ensure that the ratings assigned to the criteria are consistent with each other. This is done by comparing the consistency ratio (CR) of the pairwise comparison matrix to the acceptable CR threshold. If the CR exceeds the acceptable threshold, then the matrix is deemed inconsistent, and the ratings need revision. The consistency tests are important for the accuracy of the AHP method as inconsistent ratings can lead to inaccurate results. A CR value of 0.1 or less indicates good consistency (90% confidence) and values beyond 0.1 represent weak consistency. CR is not applicable if only two dimensions are being compared as transitivity would not be an issue.

To incorporate the judgments about the four attributes in the hierarchy, decision-makers compared the attributes one by one for each VCO product. The overall judgments for best VCO was done according to all the categories shown in Figure 4. The Criteria were compared as to how important they are to the decision-makers concerning each criterion. A pairwise comparison matrix was prepared, and a consistency test was done, which revealed that the comparison matrix was satisfactory. To form a comparison matrix, fundamental Saaty's scale for the comparative judgments was used according to Table 1.

For instance, Table 2 shows the pairwise entries for determining the weights for subcategory for the "sensory attributes" for the VCOs. The entry (Smell, color) of 7 indicates that we consider Smell to be very strongly more important than color. The AHP procedure is extensively defined in de FSM Russo and Camanho (2015). In the end, the AHP software arranges and totals the global priorities for each of the alternatives. Their total is 1.000, which is identical to the priority of the Sensory attributes.

4. Results

This section demonstrates how the decisions were made for Sensory attributes and a similar way other attributes were done. Table 2 is normalised by dividing each entry by the sum of its column.

According to the consistency test, CI/RI was $-0.06439 < 0.1$; thus pairwise matrix was satisfactory. Then the pairwise matrix for the twelve alternatives for each objective was done, and the score for each objective was calculated. A consistency check is executed to guarantee that judgments are neither random nor illogical. A consistency test was done to verify that the matrices were consistent, which is listed in Table 4.

Tables 5, 6, and 7 provide comparing matrix for VCO produces against other producers in regards to color, smell, and taste. Hence, according to the results obtained by using the AHP method $P10$ is the best alternative as a VCO producer. That is, the $P10$ producer is producing the best quality of VCO regarding the Sensory attributes, which include color, smell, and taste as its components. Table 8

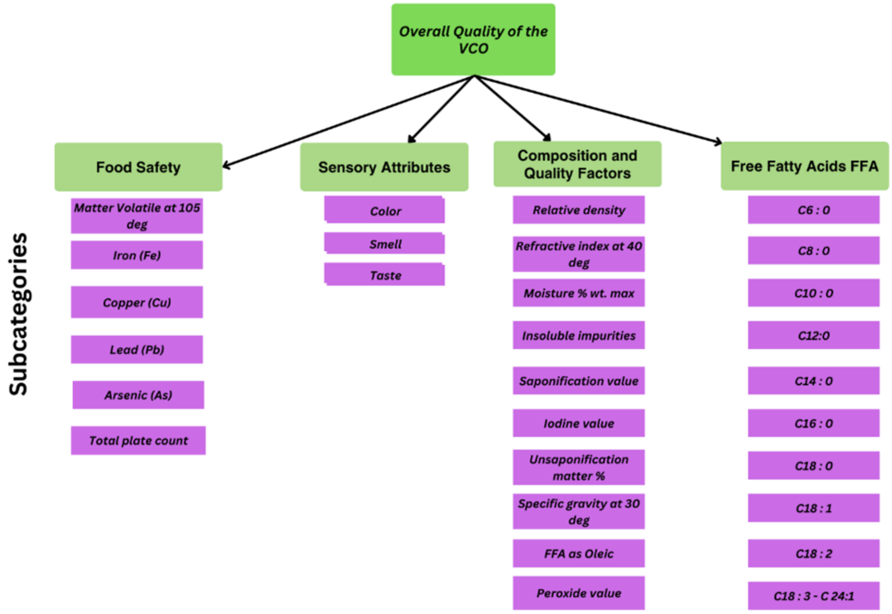

Figure 4. Categories and sub-categories used to determine the best overall VCO producer.

Table 1. The fundamental Saaty's scale for the comparative judgments.

Num. Values	Verbal Terms	Explanation
1	Equally important	Two elements have equal importance regarding the element at a higher level
3	Moderately more important	Experience or judgement lightly favours one element
5	Strongly more important	Experience or judgement strongly favours one element
7	Very strongly more important	The dominance of one element proved in practice
9	Extremely more important	The highest order dominance of one element over another
2, 4, 6, 8	Intermediate values	Compromise is needed.

Table 2. Pairwise matrix entries for Sensory attributes.

	Color	Smell	Taste
Color	1	1/2	1/3
Smell	7	1	1/2
Taste	9	7	1

Table 3. Normalised entries for Sensory attributes.

	Color	Smell	Taste
Color	0.0588	0.0588	0.1818
Smell	0.4118	0.1176	0.2727
Taste	0.5294	0.8235	0.5455

Table 4. CI/RI values for each Objective.

Objective	*CI/RI*	Comments
Color	-0.675652991	Satisfactory
Smell	-0.675632381	Satisfactory
Taste	-0.675647569	Satisfactory

provides each produces rank where 1 is the best and 12 is the worst.

Analysis for Food Safety, Composition and Quality factors, Free fatty Acids, and overall results can be combined many attributes to conclude the best VCO producer. Hence, according to the results shown in Table 9, $P12$ seems to be the best alternative. That is, the $P12$ producer is producing the best quality of VCO when it comes to the overall best VCO for all components. From Table 9,

$$P12, P11, P10, P9, P8, P7, P3, P5, P1, P6, P4, P2$$

are ranked according to their attributes from descending order. The results show that we can combine many attributes and still conclude which VCO producer is best.

5. Discussion

AHP has been recognized as an essential tool where decision making becomes a conflicting process. In this paper, AHP is utilized to solve a multi-criteria decision-making problem, which is determining the quality of VCO products released in the market by twelve different producers based on the safety attributes of APCC.

The research chose to do five separate AHP analyses; these are important in a different context to the users of VCO. Suppose one requires the best VCO for consumption or utilisation in food production. It is clear that the choice should be $P12$. However, if one may have sensory attributes over other attributes, then the best VCO choice is from $P10$.

Table 5. Pairwise matrix of Color for each VCO producers against each other.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
P1	1	1	1	1/2	1	1/2	1/2	1	1/2	1	1	1
P2	1	1	1	1/2	1	1/2	1/2	1	1/2	1	1	1
P3	1	1	1	1/2	1	1/2	1/2	1	1/2	1	1	1
P4	2	2	2	1	1/4	1	1	1/4	1/2	1/3	1/3	1/3
P5	1	1	1	4	1	1/2	1/2	1	1/2	1	1	1
P6	2	2	2	1	2	1	1	1/4	1/2	1/3	1/3	1/3
P7	2	2	2	1	2	1	1	1/5	1/2	1/4	1/4	1/4
P8	1	1	1	4	1	4	5	1	1/2	1	1	1
P9	2	2	2	2	2	2	2	2	1	1/5	1/5	1/5
P10	1	1	1	3	1	3	4	1	5	1	1	1
P11	1	1	1	3	1	3	4	1	5	1	1	1
P12	1	1	1	3	1	3	4	1	5	1	1	1

Table 6. Pairwise matrix of Smell for each VCO producers against each other.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
P1	1	1/3	1	1/2	1	1/3	1/2	1/2	1/3	1/3	1/3	1/2
P2	3	1	1/2	1/2	1/2	1/4	1/2	1/2	1/4	1/4	1/4	1/2
P3	1	2	1	1/2	1	1/3	1/2	1/2	1/3	1/3	1/3	1/2
P4	2	2	2	1	1/3	1/4	1/2	1/2	1/5	1/5	1/5	1
P5	1	2	1	3	1	1/3	1/2	1/2	1/3	1/3	1/3	1/2
P6	3	4	3	4	3	1	1/2	1/2	1	1	1	1/2
P7	2	2	2	2	2	2	1	1	1/5	1/5	1/5	1/3
P8	2	2	2	2	2	2	1	1	1/5	1/5	1/5	1/3
P9	3	4	3	5	3	1	5	5	1	1	1	1/2
P10	3	4	3	5	3	1	5	5	1	1	1	1/2
P11	3	4	3	5	3	1	5	5	1	1	1	1/2
P12	2	2	2	1	2	2	3	3	2	2	2	1

Table 7. Pairwise matrix of Taste for each VCO producers against each other.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
P1	1	1	1	1	1	1/2	1/2	1/2	1	1/2	1	1
P2	1	1	1	1	1	1/2	1/2	1/2	1	1/2	1	1
P3	1	1	1	1	1	1/2	1/2	1/2	1	1/2	1	1
P4	1	1	1	1	1	1/2	1/2	1/2	1	1/2	1	1
P5	1	1	1	1	1	1/2	1/2	1/2	1	1/2	1	1
P6	2	2	2	2	2	1	1	1/2	1/3	1	1/2	1/2
P7	2	2	2	2	2	1	1	1	1/5	1/3	1/2	1/2
P8	2	2	2	2	2	2	1	1	1/5	1/3	1/2	1/2
P9	1	1	1	1	1	3	5	5	1	1/2	1	1
P10	2	2	2	2	2	1	3	3	2	1	1/2	1/2
P11	1	1	1	1	1	2	2	2	1	2	1	1
P12	1	1	1	1	1	2	2	2	1	2	1	1

Table 8. Ranks of each VCO producer for Food Safety attributes.

Producers	Weights	Rank
P1	0.0555	12
P2	0.0559	11
P3	0.0568	10
P4	0.0580	9
P5	0.0599	8
P6	0.0879	5
P7	0.0745	7
P8	0.0824	6
P9	0.1223	2
P10	0.1240	1
P11	0.1109	4
P12	0.1118	3

The research also indicates the best VCO producer as *P*12, which can be utilized for users who are interested in all attributes.

6. Conclusion

A hierarchy for an AHP is presented in this paper for a multi-criteria decision-making problem, which is determining the quality of VCO products released in the market by twelve different producers based on the safety attributes of APCC. Subjective and objective assessment measures were developed for testing the quality of the best VCO. The weights of the each attributes were determined according to their importance to Food Safety, Composition and Quality factors, Free fatty Acids, and overall results after criticizing the significance of each attribute over the

Table 9. Ranks of each VCO producer for All attributes.

Producers	Food Safety	Sensory	Composition and Quality factors	Free fatty Acids	Overall Final
P1	12	12	11	12	9
P2	11	11	12	11	12
P3	10	10	10	10	7
P4	9	9	9	9	11
P5	7	8	8	8	8
P6	6	5	7	7	10
P7	8	7	6	6	6
P8	5	6	4	5	5
P9	4	2	5	4	4
P10	2	1	3	3	3
P11	3	4	2	2	2
P12	1	3	1	1	1

other pairwise. It was found that the twelfth, *P*12, which appeared to be the best alternative overall. The decision restored greater confidence by running the consistency test for each of the attributes.

The methodology could utilized for selecting a better VCO product. VCO producers could use this strategy for marketing, and improving their products. The work could be extended to determine the best process(Wet or Dry) for extracting VCO in the Pacific by comparing various attributes.

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