RESEARCH ARTICLE

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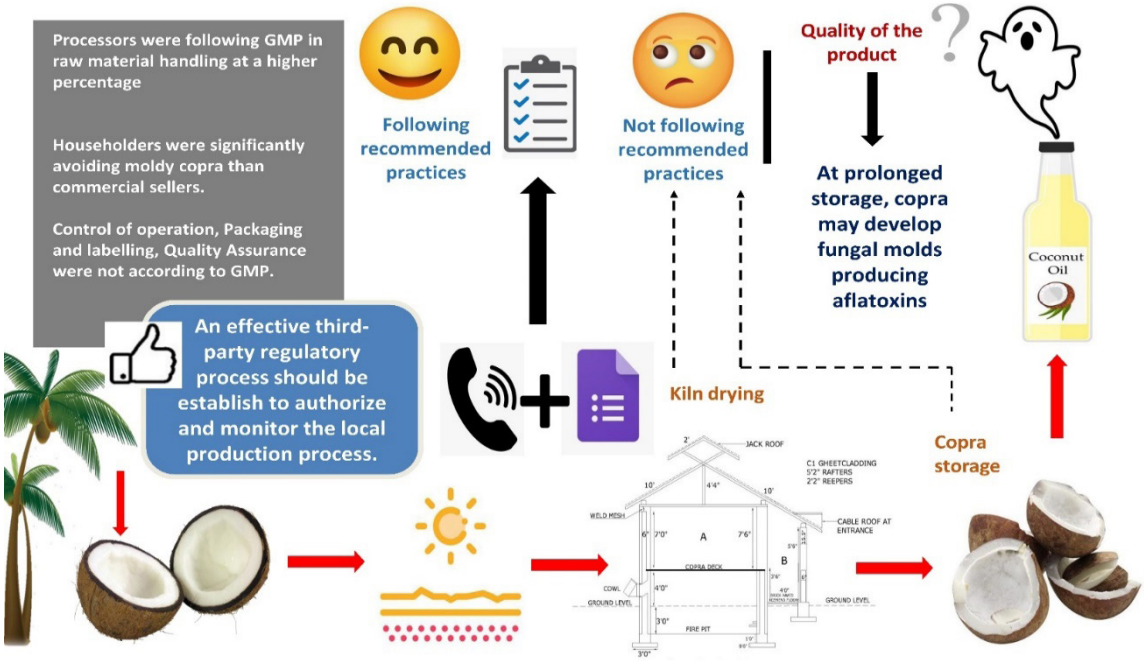

Highlights

- Overall, 54% of processors were following Good Manufacturing Practices (GMP) in raw material inspection.
- A majority were not practicing recommendations for kiln drying and storage of copra.
- Prolonged storage of poorly dried copra may capture fungal and aflatoxin development.
- Control of operation, packaging, labelling, quality assurance were not according to GMP.
- Householders were significantly ($P<0.05$) avoiding moldy copra than commercial sellers.

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Maintenance of Quality Output by Copra and Traditional Coconut Oil Processors in the Kurunegala District, Sri Lanka

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Abstract: Traditional coconut oil processing from copra using kiln drying method is considered the most suitable method for Sri Lanka in terms of economic aspects. However, mold development and Polycyclic Aromatic Hydrocarbons (PAH) accumulation could occur if good practices are not followed. With the conundrum of some imported coconut oil consignments to Sri Lanka in early 2021, the authenticity of locally produced copra-based coconut oil was also questioned. A mixed-mode survey was conducted for 65 processors in the Kurunegala District to investigate the extent of following recommendations by processors on raw material handling and process control, with reference to good manufacturing practices (GMP). The study revealed that kiln drying and storage were not according to recommendations, bringing out the possibility of developing mold and production of aflatoxins in prolonged storage. Household-level processors were significantly ($P<0.05$) following good practices to avoid contamination coming from moldy copra in comparison to commercial-level processors. In addition, processors who target local and export markets followed recommendations on process control compared to processors who target only local market. An effective third-party regulatory process to authorize and improve the processing practices to ensure the quality and safety of coconut oil is identified as an utmost requirement.

Keywords: Coconut oil processing, Copra, Good Manufacturing Practices (GMP), Mold growth, PAH.

INTRODUCTION

In Sri Lanka, coconut oil is the major edible oil used mainly for culinary purposes at the household level in addition to several other edible and non-edible applications. Coconut oil is produced from the kernel, which is the main edible tissue, of the coconut (*Cocos nucifera*). Out of different edible grades of coconut oil, traditional coconut oil is processed by a dry method using copra. Copra is a perishable food commodity obtained from mature or seasoned, de-husked, and split coconuts after drying to a specified moisture level. Copra is normally comprising of moisture 3-4% (w/w), ash 1.4-1.5%, crude fat 68-69%, crude protein 8-9%, crude fiber 6-7% and carbohydrates 7-10% (Withana-gamage *et al*., 2016). Out of the two methods carried out for copra drying, sun-drying and/or kiln drying, sun-drying is the cheapest and most efficient method which is practiced even at present by most of the household level and microscale processors. According to Thanaraj *et al*. (2007), limitations of sun-drying are; increased rate of spoilage due to intermittent and irregular way of drying, higher spoilage in storage due to higher final moisture content, variability in product quality, the necessity of relatively a larger area of land space, high labor intensity, the requirement of direct exposure to sunlight in a more precise manner and a possibility of deteriorating nutrients in exposure to higher UV (Ultra Violet) radiation from the sun.

Despite a few disadvantages of smoke drying, incorporation of smoke into the drying food matrix enhances sensory attributes of food such as its color, aroma, flavor, texture profiles and the keeping quality of food by acting as a preservative (Abdel-Naeem *et al*., 2021). According to Thanaraj *et al*. (2007), different smoking practices observed in traditional smokehouses in different countries were unsatisfactory in terms of controlling the temperature of the coconut kernels which were subjected to drying. As a result, the products were not at a desirable level of moisture content to cease the mold growth and hence accumulate the toxins produced by them. In 1960, as a solution to these malpractices observed, the "Standard Ceylon Copra Kiln" was introduced as a dryer that uses direct air heating, by replacing the "Chula" dryer (Rodrigo *et al*., 2010) in Sri Lanka. Then an improved kiln was introduced by re-designing the Ceylon copra kiln by changing a few dimensions of the initial. The kiln with new dimensions is known as the "Improved Ceylon Copra Kiln". The improved Ceylon copra kiln was recommended upon a well explainable scientific base to control copra drying by ensuring a uniform and efficient heat distribution over the coconut kernels on the platform. The drying operation recommended in this kiln includes 5 days with intermittent cooling between consecutive firings. This causes a reduction of moisture content of coconut kernels from about 43% to 8% (Rodrigo *et al*., 2010).

At present, the majority of consumers are very much health conscious, thus they consume food with an increased awareness. The coconut oil industry in Sri Lanka is encountering many issues at present making threats to

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the quality of the product and the safety of the consumers. The issues are mainly due to the presence of aflatoxins, adulteration and presence of PAH (Polycyclic Aromatic Hydrocarbons). Smoke drying method of copra processing can lead to more issues that are encountered with PAH and aflatoxin formation in comparison to other drying methods. However, it is the most frequently practiced method even today in Sri Lanka, due to its economic nature and no requirement of a very sophisticated technology or expertise to operate. Coconut kernel is a rich source of nutrients providing an ideal medium for the growth of microflora and thus leading to a rapid biological deterioration. It increases the risk of the formation of aflatoxin, which is a chemical toxin produced by a group of fungi if copra drying and storage are not done correctly with extreme care. There are two types of particular fungi that had been identified under tropical and sub-tropical climate conditions as superficial and penetrating molds which are confined to the genus *Aspergillus.* The former type appears on the surface of dry copra and is comparatively innocuous and the second type consumes the tissue of wet copra and contributes to a considerable loss by depreciation (Nalawade *et al.*, 2019).

Since the past, aflatoxin contamination in food that is intended for human consumption has become a global safety issue. Aflatoxin can be introduced as a toxic secondary metabolite of several species of fungi such as *Aspergillus flavus* Link., *Aspergillus parasiticus* Speare., and *Aspergillus nomius*. About 20 aflatoxins had been identified so far and among them, aflatoxin B1, B2, G1, and G2 are the most important as they pose serious threat to humans through food intended for consumption. Aflatoxins are introduced as carcinogenic, teratogenic, hepatotoxic, immunosuppressive, and mutagenic agents for humans on long-term exposure to a higher level than the permissible level for human consumption (Karunarathna *et al.*, 2019). Aflatoxin contamination is not an issue that emerged in the recent past however has a long history running to several decades, recording several numbers of tragedies relating to humans and animals who had consumed contaminated food items (Wielogorska *et al*., 2019).

If oil is extracted from moldy copra, produced aflatoxins pass into oil and pressed cake, and distributes more uniformly in them. Only chemical, UV radiation or microbiological treatments could be used for the complete detoxification while thermal treatments help only in partial detoxification (Diao *et al*., 2015). A major drawback revealed in smoke drying of food is the deposition of PAH produced due to pyrolysis of organic molecules during combustion, on the curing food matrix. When considering Sri Lankan copra, coconut oil, and poonac in comparison to that are produced in other countries such as the Philippines, Indonesia, etc. it is appreciable to mention the PAH level in Sri Lankan products is at a considerably lower level than the products in aforementioned countries (Wijeratne *et al*., 1996). The higher levels of PAH are mainly due to the numerous types of fuel used by those countries; coconut leaves, husks, wood, waste matters etc. along with or instead of coconut shells. However, in Sri Lanka the recommended kiln type has a reasonable scientific base ensuring a uniform heat distribution and recommends only coconut shells or charcoal powder as the operating fuel.

In Sri Lankan context, the issue of aflatoxin relating to the coconut oil sector was mainly inbounded with several consignments of coconut oil imported in early 2021. Despite the situation where the issue was encountered on imported consignments, a wider eye was opened to the domestic and local production of coconut oil, focusing that there may be aflatoxin produced in them also. According to Pathiraja *et al.* (2012) the main coconut growing and coconut-related processing areas in Sri Lanka are concentrated in Kurunegala, one of the districts belonging to the so-called 'coconut triangle', where many householders are milling oil for their own consumption, while others process coconut oil in micro and small scale for commercial purposes. Only a very few commercial mills are even under minimum requirements such as GMP certified and, the majority of commercial mills are running without any certification adhering to quality or safety management systems.

According to Coconut Development Authority (CDA), around 15-20% of the annual fresh coconut produce is used for coconut oil production, mainly as the oil extracted from copra in traditional mills to cater the domestic coconut oil requirements. According to Sri Lankan Consumer Affairs Authority (2021), about 70% of the coconut oil in the market was in lack of compliance with proper standards. According to Mendis and Rajapakse (2013), GMP can be introduced as minimum sanitary and processing requirements necessary to ensure the production of wholesome food. Out of the components listed under GMP, raw material control and process control were identified as worth to be examined in traditional coconut oil processing for a selected district. The prerequisite programs; raw material control and process control address the steps mainly carried out relating to control of incoming raw materials for the preparation and control of the food processing operations, focusing on whether they are in the prescribed range of temperature control, moisture control, control of contaminants, control of cross-contamination, and packaging and labeling requirements (Mendis and Rajapakse, 2013).

Several studies have been conducted to evaluate the authenticity of coconut oil production by analyzing some selected quality parameters of coconut oil (Moganatharsa, 2018) as prescribed by specification requirements or by analyzing microbiological parameters such as aflatoxin concentration (Samarajeewa *et al.*, 1983; Samarajeewa and Arseculeratne, 1983; Karunarathna *et al.*, 2019) and/or by analyzing chemical parameters such as PAH concentration (Wijeratne *et al*., 1996). All the studies were mainly focused on the finished product quality obtained either from processing mills or from the local market. However, the finished product in the hands of the consumer is the ultimate result of a series of actions from farm to fork. Therefore, the objective of the research was to conduct a root cause analysis, to fulfill the knowledge gap on the extent of practicing recommendations with respect to raw material control and process control by copra and traditional coconut oil processors in the Kurunegala district, Sri Lanka addressing their efforts undertaken for a quality output.

METHODOLOGY

Sampling method

For the study, the identified target population was comprised of copra or coconut oil manufacturers in Kurunegala district, Sri Lanka. The sampling unit was copra or coconut oil manufacturers. The manufacturers at commercial scale were identified according to the Coconut-related manufacturer's registration (Kernel products) list, 2017 and 2020 published by the Coconut Development Authority of Sri Lanka. Registered manufacturers in the Kurunegala district in 2017 and 2020 were 17 and 10, respectively. According to Product Service Category report by the Small Enterprises Development Division in the Kurunegala district, another 13 registered manufacturers operating since 2011 were identified. Accordingly, all the registered manufacturers of copra and coconut oil identified within the district were 40. Upon considering the kiln drying method of processing and as per the limitations in accessing the processing sites, a sample size of 37 was used for commercial processors. Furthermore, concerning the limitations in getting the exact information regarding the number of household processors and limited access *via* phone and online, a sample size of 28 was used for household processors. Simple random sampling was used and the total sample size was 65.

Mixed-mode survey

The study was conducted as a cross-sectional, quantitative study utilizing a survey questionnaire prepared in a structured and closed format. It was observed that the majority of the studies on quality management practices have utilized a quantitative approach (Kim-soon *et al.*, 2020) and it can generate a large amount of data in compliance-related studies (Karalliyadda and Kazunari, 2020). A mixed-mode survey was employed because it is the best method to generate a higher response rate than a single medium survey (Orel, 2019). Accordingly, the survey was conducted as an online survey for those who can access it easily and, simultaneously as a verbal survey over the phone for those who cannot access it online. Before the commencement of the survey, a pilot test was carried out to validate the questionnaire.

Raw material control was mainly addressed through the major variables; raw material inspection, preparation, storage and supplier control. Process control was mainly addressed through the major variables (processing steps); pretreatment, oil extraction, filtration, storage, control of operation, packaging and labeling and quality assurance. The majority of the variables addressed under raw material control and process control were in the forms of 'yes/no' dichotomous scale and multiple choice questions. A rating scale was employed to rate the experience level of processors (1-very low experience, 2-low experience, 3-moderate experience, 4-high experience, 5-great experience) and to rate the satisfaction level of the sun drying place (1-highly unsatisfied, 2-unsatisfied, 3-moderately satisfied, 4-satisfied, 5-highly satisfied). A Likert scale was employed (1-agree, 2-neither agreed nor disagreed, 3-disagree) to measure the level of agreement of processors to different opinions regarding coconut oil processing.

Statistical analysis

The Statistical Package for Social Sciences (SPSS), version 26.0 was used for database management and statistical analysis. The cut-off probability value used for testing significance was 0.05. Descriptive statistics was used mainly, and Pearson Chi-square test was used in testing some associations between few components that were used to describe the background reality of copra and coconut oil processing. The Mann-Whitney U test was used for the comparison of the level of agreement to different processing opinions, with the production period. Binomial test for comparison of proportions was used for comparison of success in following recommended practices by different groups of processors in raw material handling and process control. In addition, Spearman Rank Order Correlation test was used to test the correlation between levels of agreement of processors with the experience levels they have so far.

RESULTS AND DISCUSSION

Background analysis of copra and coconut oil processing

Respondents were recorded from 21 Divisional Secretariat Divisions under different scales of operation categorized by the number of employees engaged (Ministry of Industry and Commerce, 2015). Accordingly, operating processors at commercial level are categorized as micro (<10 employees), small (50-300 employees) and medium (>300 employees). Background information on copra and oil processing is shown in Figure 1.

According to Figure 1, processing firms certified by the latest Coconut Development Authority's 5-star concept certification seemed to be very rare in the considered sample. It was mainly due to the nature of authorizing the production procedure including the status of production premises and continuous and frequent investigations even after the finished product entered the market. The main reason for the majority without any certification status is due to the processor's motivation to achieve business goals of earning higher profit margins with minimum effort. The intention of fulfilling the demands promptly without any legal interruption is another reason for lack of certification as most of these standards are voluntary in Sri Lanka.

Upon analyzing different background components using the Pearson's Chi-square test for associations described as in previous literature, there were significant differences observed at ($P<0.05$). Data relevant to the discussion in the following section are not shown.

Associations between selected background components

The copra or coconut oil processors operating at the household level were significantly ($P<0.05$) practicing only sun drying method because of its fuel-saving nature and usage of natural radiation energy. The copra or coconut oil processors operating at the commercial level were mostly practicing only the smoke kiln drying method. The main

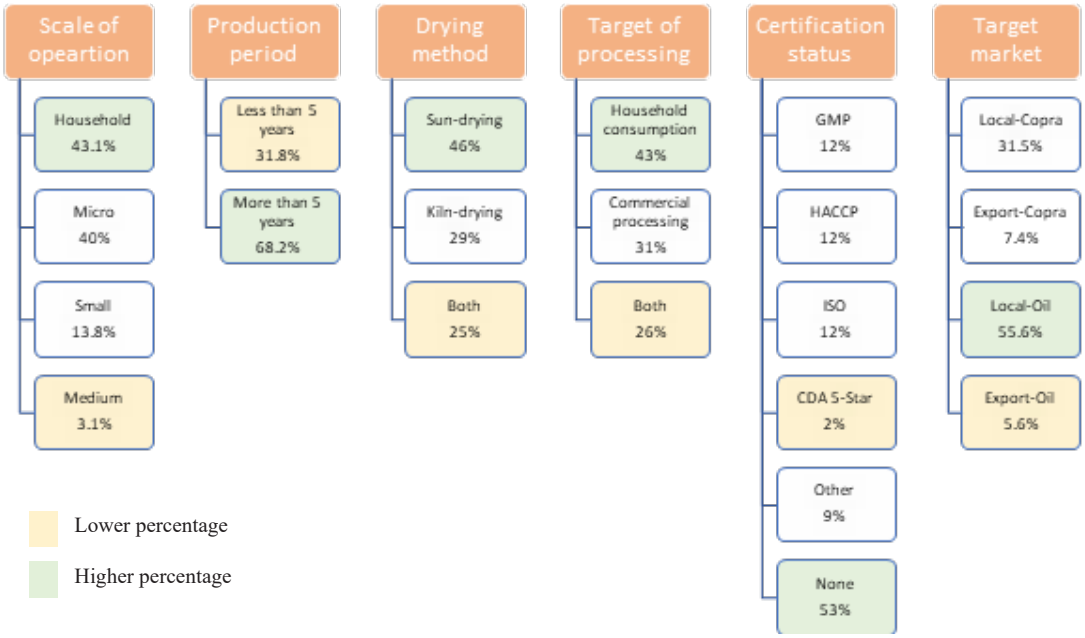

Figure 1: Background description of copra and coconut oil processing in the Kurunegala District, Sri Lanka.

reason to avoid sun-drying by them was the difficulty in meeting the frequent demands and higher chance of getting mold contaminations when the production is carried out in enormous capacities (Thanaraj *et al.*, 2007). Fuel type using for kiln drying is an important factor to be considered as it is contributing for PAH development. The majority of the processors at the commercial level (76%) were using acceptable fuels for copra production such as coconut shells, charcoal, and charcoal powder for their kiln drying process ($P<0.05$). However, the majority of the household level processors (80%) were using mostly unacceptable fuels for copra production such as coconut husks, coconut leaves, wood, paddy husk, and even waste material along with/instead of coconut shells. Due to such unacceptable types of fuel used by household-level processors, the chance of copra being contaminated by PAH is higher than that of the processors at the commercial level who were using acceptable types of fuel. The main fuel used by the processors was coconut shells and only 3.1% of processors were using waste materials as the fuel. The variation is mainly due to the high cost of fuel such as Sulphur, charcoal, and charcoal powder even on some occasion coconut shells. Coconut leaves, coconut husks, and wood are easily accessible and inexpensive in comparison to the aforementioned fuel types.

The majority of the processing firms targeting only the local market (91%) did not possess a certification status significantly ($P<0.05$). The majority of the processing firms targeting both the local and export markets (80%) were using charcoal powder as the fuel for kiln drying. The majority of the processing firms targeting only the local market (89%) were not using charcoal powder significantly ($P<0.05$). According to Rodrigo *et al*. (2010), distinctively high-quality copra such as MS (Milling Superior) and edible grades can be obtained by using charcoal or charcoal powder as the fuel for kiln drying process. Accordingly, it was evident that the majority of the processors targeting both the local and the export market (80%) were using charcoal powder as their fuel to produce high-quality grades of copra to export. Out of the commercial processing firms belonging to the participants of the survey, the majority of the processing firms operating at micro-scale (88%) were without a certification status at a significant level ($P<0.05$). The majority of the firms operating at small scale (83%) were also without a certification status. All the processing firms operating at medium scale (100%) were with a certification status.

Extent of practicing recommended quality standards relating to GMP in raw material handling

Raw material inspection

According to Figure 2, the majority (54%) of the processors were following recommended standards relating to GMP under incoming raw material inspection. The majority of the processors (48) who participated in the survey were practicing good remedies for mold-grown copra. According to Krishnan *et al.* (2009), among the penetrating molds, black (*Aspergillus niger* Van Tieghem), yellow-green (*Aspergillus flavus oryza*), and white molds later turning black (*Rhizopus nigricans* A. F. Blakeslee), the mold type interested in the survey was yellow-green (*Aspergillus flavus oryza*) penetrating type, which is the most critical aflatoxin producing group. The processors were directing the green-yellow type of mold-grown copra for non-edible coconut oil extraction but used slightly mold-grown copra for edible coconut oil extraction. However, there were coconut oil processors who used green-yellow mold-grown copra for edible oil extraction after washing or wiping off the fungus grown on copra. According to Pitt and Hocking (2009), if the storage conditions are not optimum and *Aspergillus flavus oryza* invaded, a yellow color mold development could be observed initially, and subsequently it turns green after 3-4 days. Afterward, it grows further and produces aflatoxins at their maximum by

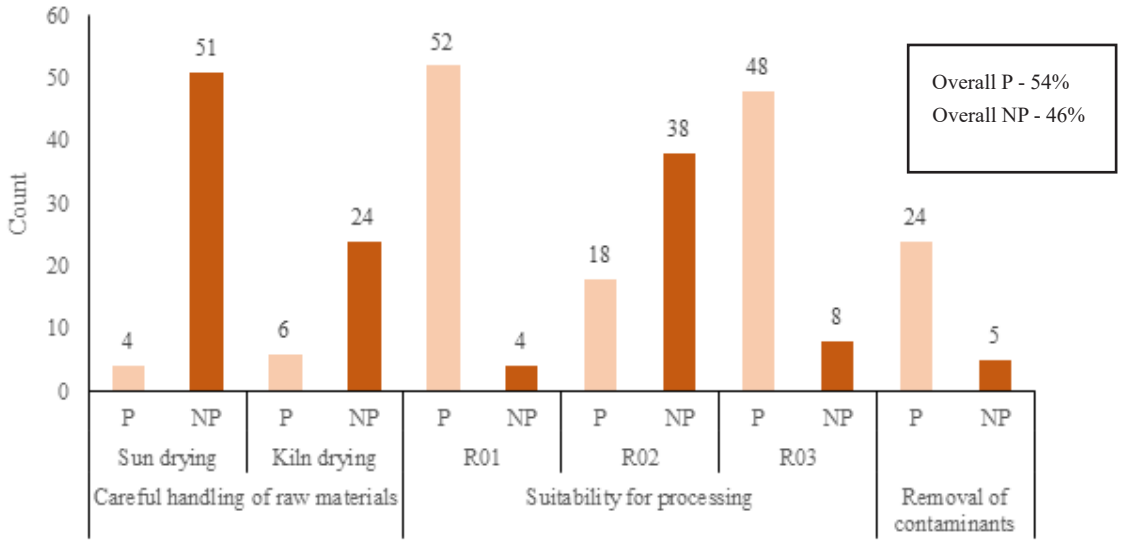

Figure 2: Extent of practicing recommended standards relating to Good Manufacturing Practices (GMP), under incoming raw material inspection. R01 - Decontamination of green-yellow mold-grown copra, R02 - Decontamination of slightly mold-grown copra, R03 - Goodness of action on green-yellow mold-grown copra. P - Overall % practicing, NP - Overall % not practicing.

penetrating the kernel. The majority (24) of the processors were following recommendations to ensure the cleanliness of copra by removing contaminants manually, using a mesh to remove extraneous substances and machines fixed with magnets to attract metallic parts.

Careful handling in the situation of sun-drying was mainly focused as it is a major cause that leads to deterioration or spoilage of processed copra. Uncovered heaps of husked nuts kept exposed to hot sun, may bring out an effect of severe cracking causing serious sliming if left overnight. The occurrence of such cracks may increase the chance of invasion by pests and worms. Hence the majority of the processors practicing sun-drying had a higher chance of subjecting to pests and worms invasion due to cracked nuts. Careful handling in the situation of kiln drying was mainly focused as the time delay it takes to apply heat treatment in the kiln after the coconuts are de-husked and split. Since fresh coconut kernel is a highly oil-bearing material with a higher percentage of water content, it is highly susceptible to rapid deterioration. According to Punchihewa and Arancon (1999), the first 4 to 8 hours after splitting can be considered a very critical period. The period of 8 hours including the time taken to split the nuts can be considered as the maximum period of delay which is permissible to avoid bacterial invasion and development. This delay is also a major cause of the development of gummy slime and dirt adhesion. Hence, the majority (24) of the processors practicing kiln drying had a higher chance of subjecting their split nuts to a rapid bacterial invasion.

Raw material preparation

According to Figure 3a, the majority of the processors were practicing recommendations, in the situation of sun-drying (69%) in terms of drying place and drying period. However, the majority of the processors were not practicing the recommendations in the situation of kiln drying (56%).

In sun drying, the recommended drying place is a 'barbecue' which is a cement-paved concrete flat constructed together with the kiln. The majority of the processors (20) were not using a similar place within the premises of the production, which was frequently rated as 1-3 in the 5 points Likert scale for satisfaction about the drying place. According to Tillekeratne (1991), 8-10 hours period of sun-drying following a kiln drying is recommended. For the processors who are following only sun drying, a period of several days is recommended. According to Figure 3a, the majority (35) of the processors were in adherence to the period of recommended sun drying.

In the situation of kiln drying, according to recommendations of the Coconut Research Institute, Sri Lanka and as shown by Rodrigo *et al*. (2010), some of the major causes leading to deterioration or spoilage of copra and the kiln dimensions were addressed in the survey as shown in Figure 2b. In a developing country like Sri Lanka, kiln drying is the most economical method if the process is carried out in the recommended manner. It is more economical as it uses naturally available resources to build up the kiln and also for the burning fuel, instead of many sophisticated technologies to operate. During the process of kiln drying, normally the temperature is around 60-65 ^{o}C. Even at this temperature, if the moisture removal from the copra surface occurs at a high rate than the rate of moisture removal from the interior to the surface, case hardening could occur. If case hardening is triggered, it ceases further moisture removal from the interior to the exterior and thus moisture inside the kernel remains (Rodrigo *et al*., 2010). However, if the kiln drying period is about 5 days with intermittent firing turns (normally 8 successive firing turns) which allows cooling between fires, the occurrence of case-hardening could be avoided. Twenty four processors were not following the recommended program for the drying procedure mainly to achieve goals of earning higher profit margins with a lesser effort and essentially to fulfill the continuous demand without a delay. On further investigation over the phone, it was

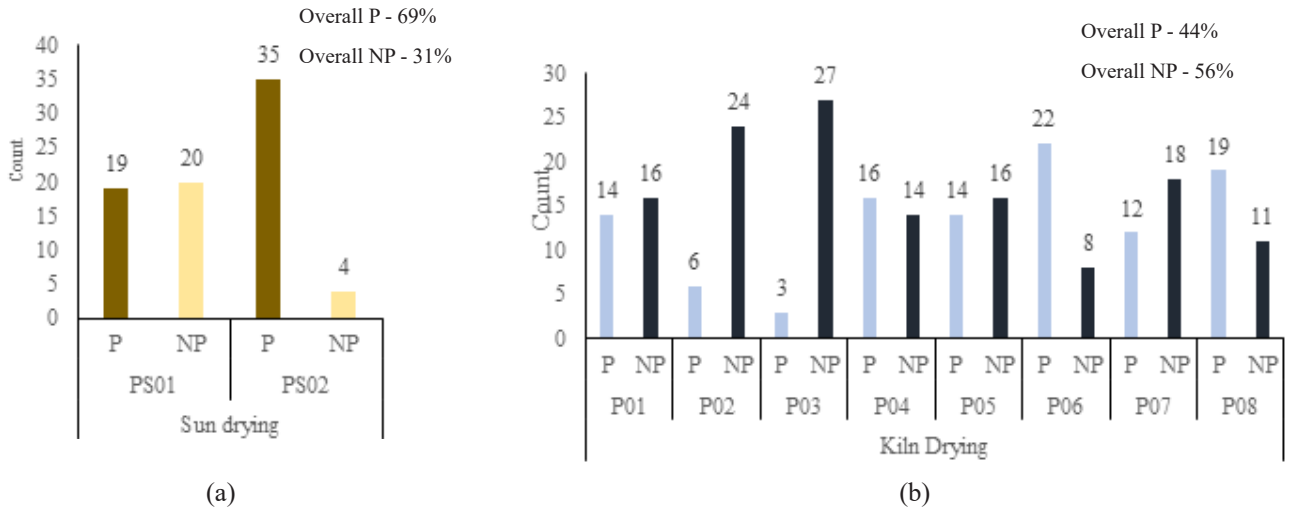

Figure 3: Extent of practicing the recommended standards relating to Good Manufacturing Practices (GMP), under raw material preparation in the situations of sun-drying (a) and kiln drying (b). PS01 - Sun-drying place, PS02 - Sun-drying period, P01 - Fuel feeding, P02 - Kiln drying period, P03 - Kiln design, P04 - Fuel type, P05 - Fuel arrangement, P06 - Fuel arranging distance, P07 - Fire pit width, P08 - Height to the copra deck. P - Overall % of practicing, NP - Overall % of not practicing.

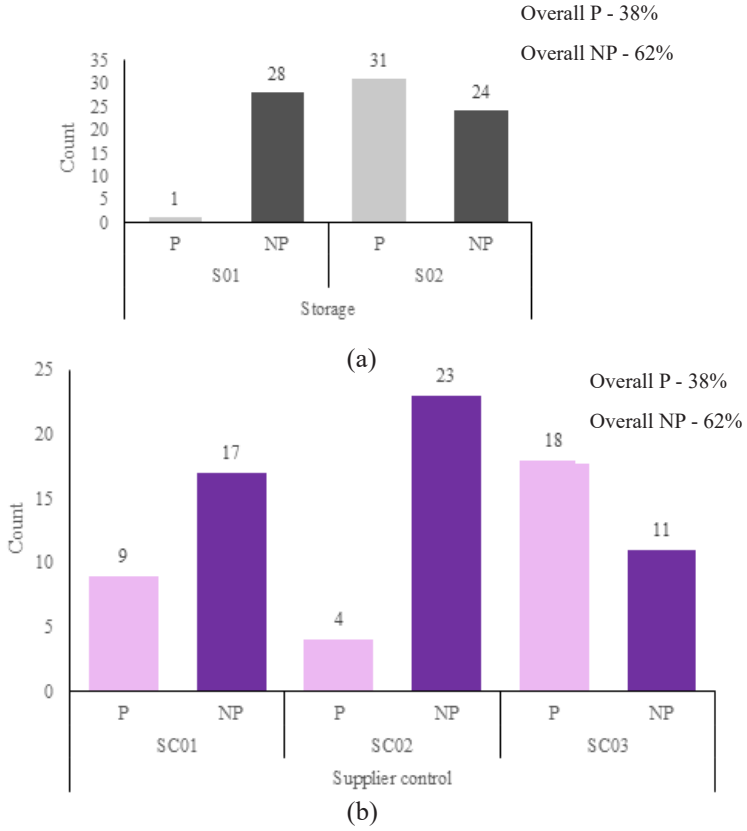

Figure 4: Extent of practicing recommended standards relating to Good Manufacturing Practices (GMP), under incoming raw material storage (a) and supplier control (b). S01 - Assurance on the relative humidity of copra storage area, S02 - Storage period of copra. SC01 - Supplier details recording, SC02 - Supplier auditing, SC03 - Statement of required grades. P - Overall % of practicing, NP - Overall % of not practicing.

revealed that the average kiln drying period was around 3 days, with non-stop firing lesser than eight successive firing turns in most of the situations. Hence the majority of the copra being processed by kiln drying has a higher chance of subjecting to case hardening with moisture left inside. This causes a profit gain to the copra seller and a loss to the buyer. Furthermore, if the storage condition is not at optimum conditions, such copra may catch mold development thus leading to the production of aflatoxins.

Raw material storage and supplier control

The number of respondents who were practicing and not practicing the recommended standards relating to GMP, under raw material storage and supplier control is shown in Figures 4a and 4b, respectively.

Table 1: The extent of practicing recommended quality standards concerning Good Manufacturing Practices (GMP) for coconut oil processing.

Processing step	Component	Overall percentage*	Overall status
Pretreatment	Size reduction (PT01)	P - 100%	Practicing
	Thermal pretreatment (PT02)	P - 24%	Not practicing
		NP - 76%	
	Both (PT03)	P - 24%	Not practicing
		NP - 76%	
Oil extraction	Prevention of cross-contamination (E01) and Oxidation prevention (E02)	P - 57 %	Practicing
		NP - 43%	
Oil filtration	Using a screening tank and a filter system (F01)	P - 59%	Practicing
		NP - 41%	
Oil storage	Oil storage period (OS01)	P - 86%	Practicing
		NP - 14%	
Control of operation	Segregation of edibles and non-edibles (CP01)	P - 28%	Not practicing
		NP - 72%	
Packaging and labeling	Package material store (PG01) and Labeling (PG02)	P - 24%	Not practicing
		NP - 76%	
Quality assurance	Quality parameter testing (QA01) and Certified (QA02)	P - 17%	Not practicing
		NP - 83%	

*P - Overall % of practicing, NP - Overall % of not practicing

Accordingly, 62% of the processors were not following recommended standards relating to GMP under raw material storage. It is very important to handle the processed copra carefully by storing them in well-ventilated dry stores and not allowing them to get wet (Kumaran, 2021). Hence, the copra storage area should need assurance on the relative humidity to reduce the chances of deterioration due to microbial invasion and also due to pests and worm attacks.

As aforementioned in Figure 3, kiln drying was not according to recommendations and had a higher chance of producing case-hardened copra. Furthermore, as the storage was also not according to recommendations, it has a higher chance of developing fungus, thus leading to production of toxins if copra is stored for a considerably longer period more than few weeks. According to Tillekeratne (1991), by reducing moisture content in copra down to 6 %, it could be stored for a few to several days rendering the oil extraction procedure easier.

On further investigation of respondents over the phone, it was revealed that the majority of the consumers were more interested in coconut oils produced at local mills than what they found on the supermarket shelf. This was mainly due to the conundrum emerged on imported consignments of coconut oil that might be subjected to aflatoxin contamination exceeding the permissible levels. Therefore, the local copra processors were frequently demanded by oil millers and they were not in a situation to store copra for a longer period than a week. Hence, it has a lesser chance of developing mold growth even though the storage of copra was not according to recommendations.

According to Figure 4b, 17 of the processors were not recording supplier details, while 23 of them were not conducting internal supplier auditing and 18 are stating the required grades to the supplier parties. Accordingly, the majority of the processors (62%) were not following recommendations relating to GMP under raw material supplier control as the majority of the processors who participated in the survey were operating at the micro and small scales without any certification status on quality and safety management systems. However, all the processors operating at medium scale were with a certification status.

Status of practicing recommended quality standards relating to GMP in process-control

The extent of practicing recommended quality standards concerning GMP in process control under stages of pretreatment, oil extraction, filtration, storage, control of operation, packaging and labeling and quality assurance is given in Table 1.

According to Table 1, all the coconut oil processors were following pretreatment at least by size reduction and/ or thermal treatment. Almost all the processors were following size reduction. However, 76% of processors were not following the both pretreatment methods.

On further investigation of respondents over the phone, the reason for employing a size reduction or thermal pretreatment was majorly to facilitate oil extraction, but also with wrong intentions to destroy any microbial colonies invaded and grown by physical cutting or allowing them to be heated over very high temperatures. Several types of molds and fungus invading copra pieces are penetrating molds and superficial molds. If the growth of penetrating

molds commences, as just the name implies the mycelium had grown deep interior and the toxin produced also diffused to the interior. As aflatoxin is a highly heat-stable toxin, the detoxification would be partial. Also, during the extraction, aflatoxins produced in mold-contaminated copra may extract uniformly into both oil and the residual cake, poonac (Bordin *et al.*, 2014).

According to Table 1, oil extraction, filtration and storage were according to recommendations while control of operation, packaging and labeling, and quality assurance were not according to recommendations. During the oil extraction process, extracted oil from good copra and deteriorated copra was not cross-contaminated and unnecessary delays exceeding a day between pressing turns were also prevented. Hence, it was clear that the oil was not subjected to free fatty acid generation and oxidation during extraction. Oil deterioration was further prevented by allowing the particles and sediments in the oil to precipitate and then filtered through a filter system without undue delay. On further investigation over the phone, the majority of the oil processors were in higher demand at the period of the survey conduction. Hence, oil was not stored after processing and packaging for more than a day. Accordingly, it was evident that there was less chance for oil being subjected to deterioration mainly in terms of oxidation.

According to GMP and HACCP - A Handbook for Small and Medium Scale Food Processing Enterprises (2005), human food should be well separated from the manufacture of non-human food-grade animal feed or inedible products. Approximately, 72% of processors were storing copra with extracted oil. If there were deteriorated copra with mold attacks, pests, and worms invaded, coconut oil processed from sound copra stored together with them might be cross-contaminated.

According to the specification "All containers should be marked as to identify the factory at which the product has been manufactured and packaged" in SLS 1590, the label should contain all the information on contact about the manufacturing and distribution. Considering the labeling status that was practiced by coconut oil processors, the majority of the processors (76%) were not labeling their coconut oil products. The respondents in the commercial sector were comprised of wholesale and retail sellers. In addition, the admixtures of the product should carry out a label on the percentages of different edible oil mixed in it. However, in early 2021, the Consumer Affairs Authority, Sri Lanka prohibited mixing any type of edible oil with coconut oil through a gazette.

Comparison of success in following recommended practices in raw material handling and process control

The processors who were following recommended practices regarding raw material inspection in terms of suitability for processing was compared between the processors of commercial level and the household level. In addition, variables addressed under kiln drying and process control were also compared between processors targeting only local market and both local and export markets. According to Marikkar *et al*. (2009), sun-drying which was the most practiced method at the household level would increase the chance of mold contamination. This higher possibility is due to exclusion of smoke in sun-drying and also its intermittent nature if rainfall persists. Accordingly, Binomial test was used for comparison of proportions with respect to avoiding mold-grown copra for edible oil extraction by household level and commercial level processors. The summary of the results is given in Table 2.

According to Table 2, there was a significant difference ($P<0.05$) in following good practices in selecting raw materials suitable for processing, at the household level and commercial level. The proportion of those who were following recommended practices at the household level is significantly ($P<0.05$) higher than that of the commercial level. According to Table 2, this overall significant difference was due to the significance observed for decontamination and goodness of actions undertaken for avoiding green-yellow mold-grown copra. The proportion of those who were avoiding green-yellow mold-grown copra for edible oil extraction was higher for the group processing at the household level. It may be due to the increased awareness within the society where timely discussions have emerged regarding the conundrum of some imported coconut oil consignments to Sri Lanka. However, the use of such copra by commercial level processors could be to achieve the

Table 2: Comparison of success of following recommended good practices in raw material handling, preparation for kiln drying and process control between selected groups.

Component	p-value	Significance
Selecting raw materials suitable for processing at household level and commercial level		
Decontamination of green-yellow mold-grown copra	0.02	SD
Decontamination of slightly mold-grown copra	0.47	ND
Goodness of action on green-yellow mold-grown copra	0.06	SD
Overall suitability for processing in terms of avoiding mold-grown copra	0.016	SD
Kiln drying and process-control by processors targeting only local market and both local and export markets		
Kiln drying	0.992	ND
Process control	0.007	SD

SD - Significant difference, ND - No significant difference

intended business goals of attaining higher profit margins and maintaining the continuous supply.

There was no significant difference (P>0.05) in practicing recommendations for kiln drying between the two groups of processors: targeting only the local market and targeting both local and export markets. There was a significant difference (P<0.05) in practicing recommendations in process control between these two groups of processors. The reason might be mainly due to the procedure carried out in process control according to buyer requirements of exporting countries. Most of the processors targeting both local and export markets were practicing recommendations according to quality and safety management system standards than the processors who were targeting only the local market.

Opinions on coconut oil processing

Comparison of the level of agreement to statements between groups of processors engaged in production, lesser than/greater than 5 years and correlation between the agreement to the statements with the experience level of processors are given in Table 3 and Table 4, respectively. For the above analysis the Mann Whitney U-test and the Spearman rank order correlation were used, respectively.

The majority of the respondents (42%) who participated in the survey neither agreed nor disagreed with the aforementioned opinions on processing (data not shown). According to Table 3, this status of unbiased for the opinions was not significantly different (P<0.05) over the production period. Both groups of processors who engaged in production lesser than 5 years and for more than 5 years remained unbiased for their opinions. According to Table 4, there was a statistically significant positive correlation (r_s = 0.405 and P<0.05), between disagreement for statement 3 (some types of molds growing in copra can be removed completely upon washing) with the increased experience level of the processors.

According to Paterson and Lima (2010), a common opinion popular among millers is that accepting that greyish blue-colored mold growth by *Penicillium* is better than green yellow-colored fungal growth. It is believed that greyish blue color fungus is growing at low moisture content and hence, it can be assured that copra contaminated with such molds are dried better than copra contaminated with green-yellow fungus. In addition, a very obsolete opinion regarding aged copra was that oil yield gradually increases when the copra is allowed to age. This was also observed among a few of the processors. This is completely incorrect because it renders the same amount of oil as from non-aged copra, however in poor quality (Hammonds and Harris, 1987). Another common opinion observed among some of the coconut oil processors at the commercial level was that some types of mold-grown in copra can be completely removed upon washing. Mainly this practice was carried out for green-yellow colored mold-grown copra. The fungus which is in yellow-green considered to be producing aflatoxins at its maximum level (Sekar *et al*., 2008) and has started penetrating the kernel deep inside. Few of the processors operating at the commercial level believed that size reduction by cutting the copra in half during pretreatment also removes the molds grown. Accepting that the substances produced by molds may be destroyed by subjecting to higher temperatures was

Table 3: Comparison of the level of agreement to statements with the production period

Statement	p-value	Significance
Greyish blue-colored fungus is better than green yellow-colored fungus.	0.981	ND
The oil yield gradually increases when the copra is allowed to aging.	0.793	ND
Some types of molds growing in copra can be removed completely upon washing.	0.905	ND
Substances produced by molds may be destroyed when subjected to higher temperatures during oil extraction.	0.981	ND

ND - No significant difference

Table 4: Correlation between agreements to statements in coconut oil processing with the experience level of processors.

Statement	Experience level		
	r_s	p-value	Significance
Greyish blue-colored fungus is better than green yellow-colored fungus.	0.150	0.437	NS
The oil yield gradually increases when the copra is allowed to age.	0.224	0.243	NS
Some types of molds growing in copra can be removed completely upon washing.	0.405	0.029	S
Substances produced by molds may be destroyed when subjected to higher temperatures during oil extraction.	0.190	0.324	NS

NS - No significance, S - Significant, r_s - Spearman correlation coefficient

also observed among a few processors, in the belief that thermal treatment before oil extraction destroys some types of molds grown and the toxins produced. Only chemical, UV radiation or microbiological treatments could be used for the complete detoxification while thermal treatments help only in partial detoxification (Bordin *et al.*, 2014).

The study is not entirely focusing on the processor's compliance with quality management standards. But the study has used the standards and recommendations as a scale of reference to determine the efforts undertaken for a quality output by the processors. As the study is having an appearance of a compliance-related study, it possesses a sensitive nature and a possibility of non-compliers operating at the commercial level to withhold participation in the survey or provide misleading answers (Karalliyadda and Kazunari, 2020).

CONCLUSIONS

The two critical stages in the copra production process; kiln drying and raw material storage were not according to recommendations, creating a higher chance of developing molds and production of aflatoxin if the copra is subjected to prolonged storage. The processors at the household level were significantly following ($P<0.05$) recommendations than those at the commercial level concerning the suitability of copra for processing. The majority of the processors were not following recommendations in raw material preparation in the situation of kiln drying, storage, supplier control and control of operation, packaging and labeling, and quality assurance. The majority of the processors at the commercial level neither agreed nor disagreed with the statements focused on opinions relating to processing. A statistically significant positive correlation ($r_s = 0.405$ and $P<0.05$) was observed for disagreement on the statement; washing completely removes molds grown on copra with the increasing experience level of processors. It is vital to ensure the traditional method of coconut oil processing using copra is adhering to good practices and recommendations by strengthening the legal framework. In addition, it is recommended to initiate an effective third-party regulatory process to authorize and improve the commercial-scale practices and to increase the awareness of the local processors especially regarding correct facts relating to processing and guidelines on good manufacturing practices to be followed. It is noteworthy to emphasize the usage of hot air dryers for kernel drying as the best method to prevent issues adhering to the traditional kiln method of copra drying.

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DECLARATION OF CONFLICTS OF INTEREST

The authors declare no competing interests.

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