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Benchmarking Study of *Cymbopogon citratus* and *C. nardus* for Its Development of Functional Food Ingredient for Anti-diabetic Treatment

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Abstract: *Cymbopogon citratus* and *Cymbopogon nardus* are two species of Cymbopogon that are commonly cultivated in Indonesia. Studies have shown Cymbopogon activities and potencies for development for various diseases including diabetic treatment. Both *C. citratus* and *C. nardus* have long history for culinary and medicinal herb in Indonesia and therefore have a sustainable commercial production that will support their development for functional food ingredient. This work provides a study about industrial observation in several herbal industries along with literature review of herbal industries condition in Indonesia as a benchmarking study to summarize the required research or technical development of Cymbopogon as functional food ingredients. During industrial observation it was shown that Cymbopogon usage in herbal industries were more popular as flavorings rather than for its functionalities. The industrial observation to several reputable herbal industries showed that despite the similar infrastructure used for extraction and pulverization method, the industries might have different supply procurement and quality requirement, extraction principle, product character and quality control, and therefore market character. The literature review have shown several studies of Cymbopogon functionalities in organic solvents, empirical uses of Cymbopogon as medicinal herbs in water extract, optimization in Cymbopogon cultivation. Heavy studies have been done in the extraction, usage, and characterization of essential oils from Cymbopogon. Many literature showed formulation of Cymbogon for culinary purpose but there are yet formulation based on its functional activities. Both industrial observation and literature review called in the requirement of more study of activities and stabilities of the Cymbopogon aqueous and ethanolic extracts, optimization of post-harvest processing, extraction, and further processing to produce Cymbopogon ingredients based on activities and efficiency, and the determination of active fraction/compound(s) responsible for the activity and formulation of food that will enable the usage direction of functional food ingredients.

Keywords: Cymbopogon citratus, Cymbopogon nardus, food ingredients, herbal industry

1. Introduction

Indonesia, among other Asian countries, has a long history of making use of herbal ingredients in their daily life. The application of many herbs and medicinal plants has grown as a tradition in the society and become the legacy of the people, inherited from generation to generation. In a modern world as today, the tradition to use local plants as culinary ingredients and remedies for several illnesses has not faded, it has even matured into an integrated life-style among the Indonesian younger generations. *Pachyrhizus erosus*, also commonly known as *bengkuang* in Indonesia is one root of a plant that has been long known trusted to lighten skin tone, and has been widely applied both traditionally and commercially as skin whitening treatment in form of lotions, peeling scrubs and soaps. A wide range of *capsicum* family or chilies is popular to gain male vitality, while *Curcuma xanthorrhiza* (Javanese ginger, *temulawak*) is popular not only for beauty care but to also cure various illness and to boost children appetite.

The history of Indonesian herbal industry has started hundreds of years ago with the born of *jamu* tradition. Jamu is a local terminology used to describe herbal medicines made from natural materials, such as leaves, roots, barks, seeds, or flowers of a plant. Jamu was claimed to be the heritance of one of the Javanese kingdoms, where the royalties and nobles mainly maintained their health and beauty by making use of traditional ancient recipes. With a good health and beauty of the ladies being maintained, jamu was trusted to be one of many other things that can preserve a family harmony.

As it entered the 20th century, jamu seemed to lose its popularity for having been seen to have a low image in the society. The reason of this was merely due to the increasing awareness of local people about hygiene, they saw that jamu as a traditional product was produced using non-standard traditional process, unhygienic both in the processing and distribution, and mostly because the lack of scientific proofs of its benefits. It was said, that not until around 1940s, jamu has regained its popularity, and physicians' interest on jamu had increased, although still until now, their opinions are rather ambivalent. During decades afterwards, commercialization of Indonesian jamu and herbal industries has grown, and more scientific studies have been conducted to prove the benefits of Indonesian herbal plants based on their local wisdoms.

One of the beneficial local herbal plants, which is applied as food and herbal ingredient in Indonesia is *Cymbopogon*, or commonly known as lemongrass or *"serai"* in Indonesia. An industrial observation conducted in scope of a previous research has shown that the use of lemongrass for culinary purposes and as jamu ingredient has been intended to obtain its aroma and flavor, which not only add richness to the product taste but also give a tint of relaxation sensation through it (Widiputri et al. 2017). On the other side, many studies have proven that lemongrass can apparently provide more than aroma and flavor, since it contains different bioactive compounds that can be responsible for many functionalities, among others is as a treatment for diabetes (Arsiningtyas et al, 2014). Since this beneficial functionality is not yet widely explored in the Indonesian herbal industries, heavy studies on the potency of lemongrass as diabetic treatment has been conducted in the Faculty of Life Sciences and Technology, Swiss German University, Indonesia. Nevertheless, there is still a need to wider explore the industrial application of lemongrass extract as functional food and herbal medicines ingredient. Thus, in this work, a benchmarking study to observe different processing practices in several Indonesian herbal industries was conducted.

2. Application of Cymbopogon Plants in Indonesian Herbal Industries

2.1. Herbal Industry Requirements

Development of herbal products in industrial scale needs to have stronger scientific background to prove the benefits and is also encouraged to fulfill the requirements of people's health for remedies and treatment of illness recognized from medical researches, so that in the future, the herbal medicines can attract bigger interest from physicians, be covered by health insurance, and become a player in the frontier medicine, like they currently are in Japan (Suzuki et al. 2004).

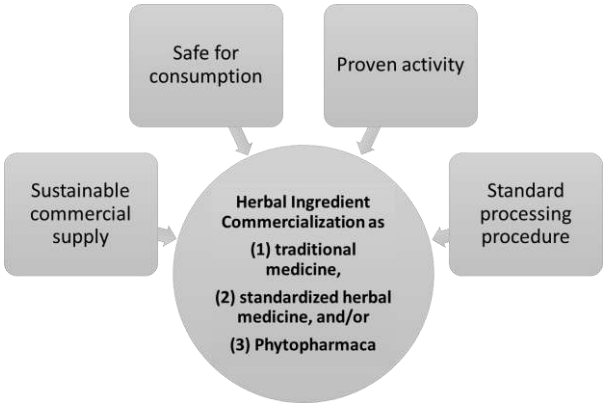

Figure 1. Requirements of herbal industry.

Figure 1 shows the requirements for herbal industry, besides the need to have a scientific background of proven activities of the ingredients they use. A commercially produced herbal product must be produced through a standard processing procedure, be able to sustainably provide commercial supply, and at the very first place must be ensured its safety for consumption. There are three categories of herbal ingredient products to be commercially prepared in Indonesia, namely traditional medicine (jamu), standardized herbal medicine, and phytopharmaca. The three categories differ from each other based on their quality, safety and efficacy. Traditional medicines or jamu is registered herbal product with a brand name, which is consisted of one or more powder herbal ingredients, and are commonly used by the community based on existing empirical experiences. Standardized herbal products differs themselves from traditional ones by theirs contents, which mostly consist of standardized extract alone or in combinations, or can also be consisting of one or more powder herbs, whose therapeutic use must be based on pre-clinical studies evidence. While the therapeutic use of phytopharmaca must be based on clinical studies (WHO 2005). It was reported that more than 10,000 herbal products have been marketed in Indonesia until March 2018, however, due to the limited qualified clinical studies, only 21 phytopharmaca have been registered in Indonesia until April 2018 (Usia 2018).

2.2. Cymbogon citratus *and* C. Nardus *as Herbal Ingredient*

Cymbopogon citratus and *Cymbopogon nardus* are two species of Cymbopogon that are commonly cultivated in Indonesia. The availability of both species are very abundant in Indonesia, with the plantation area reaching 3,492 hectares (Dirjen Perkebunan, 2006). The two species differentiate each other not much from their appearance; however, *C. nardus* is recognized to have slight reddish color at the beginnng part of the plant. Nonetheless, they are used in different applications by the community for being known to have different strength of aroma. *C. citratus* or commonly known as simply lemongrass, is mainly used as prominent ingredient in Thai cuisine and also Indonesian traditional foods and beverages. Meanwhile, *C. nardus*, or commonly known as citronella grass or aromatic grass, is more used to produce essential citronella oil, or fractionated into citronellal, citronelol, and geraniol. Citronella grass is also commonly used as flavoring in cooking and tea preparation, as well as in perfumes for having a stronger aroma.

Both species of Cymbogon plants have been traditionally used since they were found to be able to maintain and/or promote human's health, and to some extent can also act as a remedy to reduce pains and illnesses. *C. nardus* is trusted to maintain blood glucose, hypertension, as an anti-cancer, insect repellent, and promoter of internal detoxification. It is also found to be able to treat flatulence, indigestion, intestinal cramps, irritable bowel, and gastritis. Similarly, the traditional use of *C. citratus* was believed to be able to reduce blood glucose, body weight, cholesterol, as well as to treat insomnia, detoxification, maintaining skin health, and treat indigestion.

Recent studies on the functionalities of *C. citratus* or lemongrass have scientifically proven that this plant shows the presence of *α-glucosidase* and *α-amylase* inhibitory activities, which can be responsible to inhibit the conversion of complex carbohydrate entering the human body to blood glucose. Previous research has shown the in-vitro *α -glucosidase* inhibition activity and in-vivo activity to delay blood glucose elevation after oral sugar treatment (Gunawan-Puteri et al. 2018). With the presence of these activities, lemongrass extract can be used for cnti-diabetic treatment (Gunawan-Puteri et al. 2016).

Despite all the research founding mentioned in the above passage, the industrial application of lemongrass in functional foods and beverages, as well as in traditional herbal medicines in Indonesia has not been focused on taking benefit of its α-glucosidase inhibitor (AGI) and α-amylase inhibitor (AAI) activities yet. Hence, no process optimization has been made with the purpose to produce lemongrass extract with optimum AGI and AAI activities, until quite recently, several researches have been performed to study the impact of different extraction process on inhibitory activities (Gunawan-Puteri et al. 2016), effect of different pre-treatment scenarios, and the stability of the lemongrass extract produced through an optimum process (Widiputri, 2017).

2.3. Industrial Observation to Reputable Indonesian Herbal Industries

In its application in industrial processes, there is a tendency of *C. nardus* to be used in large industries as part of many medicinal herbs formula, due to its desirable flavor. Meanwhile, *C. citratus* is more used in

small and medium enterprises (SMEs) of medicinal herb formula, due to expected activity. In the scope of this work, an industrial observation to several Indonesian herbal industries was conducted, in order to study the comparison of different practicable processes required in the production of herbal ingredients for commercial use. From this observation, it was understood that several large industries employ similar infrastructure used for extraction and pulverization method with the latest technology and machineries and have employed ISO standards. SMEs on the other hand, have varied processing facilities and employ bigger number of human labour for the processing purpose. The differences between various large industries and SMEs observed in this work were noted in their supply procurement, raw material quality control, processing (includes raw material handling and ingredient preparation for formulation), and product quality control.

Table 1: Comparison of industrial process of herbal products in Indonesia.

	Supply procurement	**Raw material quality control**	**Processing**		**Product quality control**
			Raw material handling	**Ingredient preparation/ formulation**	
Traditional Industry	From farmers	Freshness confirmation	Washing	Mixing, water extraction	None
Industry A	Direct supply from farmers	• Farmers training • microbial check	Washing and drying	Mixing, ethanolic extraction, evaporation into paste form, oven drying	In-vivo trial, user testimony, sensory evaluation
Industry B	Contract distributor	• COA (certificate of analysis) • Bioactive compound confirmation • microbial check	Washing and drying	Ethanolic extraction, evaporation into paste form, oven drying, mixing	Bioactive compound confirmation
Industry C	Direct supply from farmers	Farmers training	Washing and drying	Mixing, grinding	User testimony

Table 1 summarizes the comparison between 4 (four) industries, including large industry and SME, and one traditional industry. The first difference that can be noted is based on how those industries conduct their supply procurement and how they control the quality of their raw material supply. Different industries will tend to decide between 2 options in obtaining their raw materials; through direct supply from farmers or through contract distributors. The chosen way to obtain their raw materials will dictate the required raw material quality control. If one industry decided to get their raw material directly from farmers, then they need to ensure that the farmers understand the required specifications and hence acknowledged with the proper harvesting and post-harvesting activities. This can be achieved through trainings for farmers. When it was decided to hire a contract distributor for supplying raw materials, it can be expected that they provide a certificate of analysis (COA) of bioactive compounds content. Both options should be completed with internal check of freshness and microbial activities once the raw material has arrived on-site.

The next comparison can be made based on the raw material processing to form herbal ingredient/product. A quite wide range of options was observed from the 4 industries being compared in this work. Although some industries can apply similar processing principles, equipment and machineries, they can still have different decisions in selecting their processing steps and process sequences. As an example, in handling the raw materials prior to the main process (during pre-treatment of raw materials), one industry can decide to wash their raw material either once or twice, or they can also decide to use their raw materials directly without washing. After washing process, the industries can decide whether or not they need to dry the raw materials prior to the next processing stage. A very important difference can be observed in the main preparation of herbal ingredients and/or its formulation. It can be chosen whether one industry will do the formulation prior to extraction process or after the production of single extract alone. In the latter case, the expected bioactive compound of each

extract alone can be ensured, so that the product formulation afterwards can be aimed at desired activity. In terms of the extraction itself, the solvent can differ, depending on the type of bioactive compound that is intended to be extracted. Lastly, the finishing of the product can also vary between liquid extract, dried extract without grinding, and powder extract. These alternatives of processing steps are listed in Table 2.

At the very last stage of the observation, the method used to control product quality was compared between the four industries. It was observed that the variations of the means for product quality control were varying between no quality control, through empirical study, in-vivo trial, and/or through confirmation of bioactive compound in the final product.

Table 2: Variation in processing methods for the production of herbal products

Types of raw material pre-treatment	Types of product formulation	Types of extraction	Type of product finishing
• unwashed / 1X / 2X washing • drying / no drying	• prior to extraction • post extraction and pulverization	• no extraction • water extraction • ethanolic extraction followed by evaporation and oven drying	• liquid / concentrate form • dried product without size reduction • pulverization with direct grinding of dried product

3. Scientific Research Development and Recent Studies on the Application of Cymbopogon as Herbal Ingredient with AGI and AAI Activity

The conducted industrial observation above has led to an awareness for academicians to develop research studies on the application of Cymbopogon as herbal ingredient with AGI and AAI activity. Understanding that all steps of processing from procurement to product quality control must be selected based on the required functionalities and activity of targeted bioactive compound, plenty need to be done in order to produce Cymbopogon extract that can be applied as herbal product to treat diabetes.

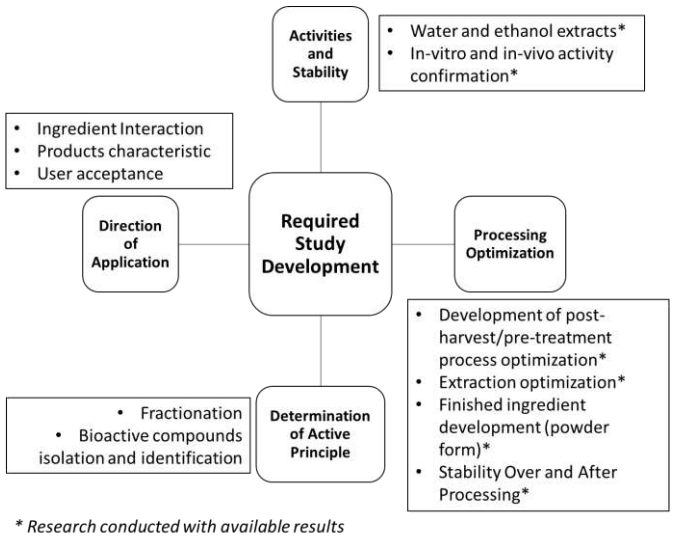

Figure 2. Required study development on the application of Cymbopogon as herbal ingredient with AGI and AAI activity.

Figure 2 depicts the required study development, comprising four essential areas that must be explored. Firstly, the AGI activities and stability of Cymbopogon extract both in water and ethanol must be known, since only by having this information a claim can be made scientifically, that the resulting product does indeed have the ability to reduce blood glucose level after certain sugar or carbohydrate intake. For this purpose in-vivo activity was confirmed in a previous research, where it was shown that

lemongrass extract was able to delay the blood glucose rise after oral sugar treatment in dose dependent manner. However, concentration of 10 g/kg BW was not recommended due to its sharp reduction that may lead into hypoglycemia (Gunawan-Puteri et al. 2018).

Simultaneously with the determination of extract activity and stability, process optimization must take place, since the selection of proper processing method, starting from post-harvesting until product finishing process (e.g. drying and pulverization), will affect the AGI and AAI activity of Cymbopogon extract. From several studies, the optimum extraction method was obtained for both water and ethanol extraction. When using water extraction, the recommended processing procedure will be to perform the extraction under stirred maceration, at 70°C, for 40 minutes. However, ethanol extract was found to generally have higher AGI activity than water extract (Gunawan-Puteri et al. 2016). An optimization of pre-treatment process of Cymbopogon before it undergoes the extraction process was also conducted. From this research, it was suggested to wash the fresh plant only once and directly followed by an oven drying at 40°C, to maintain the AGI activity at optimum level (Widiputri et al. 2017). In the same work, the stability of the resulting lemon grass extract was studied. The shelf life of the extract was found to be ± 8 months (at 5°C), ± 3 months (at 25°C) and ± 1.5 months (at 30°C).

After optimum processing was determined, the next crucial stage of the study is to perform fractionation and bioactive compounds isolation and identification. Lastly, there is a need to develop direct application for consumers through products development that contain Cymbopogon extract with optimum AGI activity. For this purpose, the interaction between Cymbopogon extract and other ingredients used in the intended food or beverage product must be studied, followed with a sensory analysis to obtain overall user acceptance. In the Figure 2, all research areas marked with an asterisk symbol are already conducted with satisfactory result, while the rests are still ongoing.

4. Conclusion

Cymbopogon citratus and *cymbopogon nardus* as two species of Indonesian local plants are very promising in their application for anti-diabetic treatment. The benchmarking and literature study performed in this work has revealed the necessary direction of research study development, in order to enable the commercialization of lemongrass extract as food and medicinal ingredient for treatment of diabetes.

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