January 2022

THE SECOND INTERNATIONAL CONFERENCE ON GENETIC RESOURCES AND BIOTECHNOLOGY: Harnessing Technology for Conservation and Sustainable Use of Genetic Resources for Food and Agriculture

Committees: The Second International Conference on Genetic Resources and Biotechnology

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Preface: The Second International Conference on Genetic Resources and Biotechnology

The Second International Conference on Genetic Resources and Biotechnology, which is the continuation of the first event held in 2018, focuses on topics related to advances in biotechnology to create more opportunities for effective conservation and sustainable utilization of genetic resources for food and agriculture. This year conference's theme is Harnessing Technology for Conservation and Sustainable Use of Genetic Resources for Food and Agriculture. The conference was organized by Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture, Indonesia, in collaboration with Indonesian Biotechnology Consortium and held on 24th-25th of May 2021virtually due to the pandemic of COVID-19.

The conference aims to share and exchange current scientific information and technological developments on biotechnology and their applications for conservation and sustainable use of genetic, to encourage and promote quality, efficiency, and modernization of management and utilization of genetic resources, and to facilitate national and international collaboration among participants. There are five scopes discussed in this conference. They are effective management of conservation and sustainable use of genetic resources for food and agriculture, application of genomics and molecular markers for genetic resource conservation and crop adaptation to climate change, application of innovative crop improvement techniques for conservation and sustainable use of plant genetic resources for food and agriculture, plant cell and tissue culture for conservation and effective utilization of genetic resources, and the use of microbial genetic resources as biological control agents of agricultural pests and diseases, and for soil bioremediation.

Five speakers from the United States of America, Japan, India and Indonesia were invited to discuss about their expertise and knowledge on relevant subjects in the plenary sessions. This conference was attended by more than 100 participants including 75 presenters and 44 listeners worldwide. They came from diverse governmental, private, or academic institutions and also scientific communities. The presented materials have undergone peer review processes and only qualified papers were selected. Furthermore, all papers were subjected to double blind peer-review and expected to meet the scientific criteria of significance and academic excellence to be published in a conference proceedings indexed in a well-known, reputable service.

We would like to express our sincere gratitude to our speakers, presenters and all participants for their contributions in this conference. We would also like to express our appreciation for the generosity of our sponsors that support this conference: PT CropLife, PT ITS Science Indonesia, PT Fajar Mas Murni and PT Prima Instrument Analitika. Lastly, special thanks to all committee members for their exceptional work and contributions in the conference and publication.

Chair of Organizing Committee

Dr. Toto Hadiarto

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Genetic resources of adlay (*Coix lacryma-jobi* L.) in East Kalimantan as source of functional food

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Fitri Handayani, Muhammad Amin and Muhammad Taufiq Ratule

Genetic Resources of Adlay (*Coix lacryma-jobi* L.) in East Kalimantan as Source of Functional Food

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Abstract. Adlay (*Coix lacryma-jobi* L.; also known as job's tears) contains bioactive compounds with various health effects, and could become source of functional food. Limited information about its chemical composition and health benefits hinder the development of this plant. This review summarizes the bioactive compounds, health effects, as well the genetic diversity of adlay in East Kalimantan and its development strategy as source of functional food. Adlay contains a range of bioactive compounds including carbohydrates, proteins, lipids, vitamins, polyphenols, flavonoids, phenolic acids, lactam, and spiroenone. These chemical constituents may promote human health by their role as antioxidant, anticancer, antiproliferation, anti-inflammation, immunological modulation, antidiabetic, and anti-obesity. High genetic diversity of adlay in East Kalimantan is an opportunity to select superior cultivars by exploration and identification. Superior cultivars in accordance with local people preference are potential to be developed as sustainable crop. Support of regional government plays a very important role in the development of adlay local cultivars.

INTRODUCTION

East Kalimantan is the fourth largest province in Indonesia. With a total area of 127.346 km2 (6,6 % of Indonesia's total area) and located on one of the world's flora center islands. East Kalimantan has high biodiversity and high plant genetic diversity. Some of them have been utilized by the community as sources of food.

Adlay (*Coix lacryma-jobi* L.; also known as job's tears) is cereal crop which has high genetic diversity in East Kalimantan, and potential to be used as staple food alternative. Food products from adlay are adlay rice (called as grits) and adlay flour. Grits can be used as substitute for rice, or as a mixture of rice in daily meal. Meanwhile, adlay flour can be used as a substitute or made as a composite with wheat flour. Furthermore, adlay is also widely used as an ingredient in herbal medicine because of its chemical content [1–4]. In China, adlay has been known and used as food and medicinal ingredient since 28,000 BC in the Paleolithic era [5]. In Indonesia, adlay is still rarely known, so its use as food and medicine is still limited.

Efforts to introduce and promote adlay as an alternative staple food to support food diversification and self-sufficiency program in East Kalimantan Province has been carried out since 2011, especially in Kutai Kartanegara and Samarinda Regencies. The efforts included the selection of superior accessions of adlay wild relatives and seeds purification, demonstration of adlay cultivation in demo plots of local cultivars, introduction of various food products of adlay at some events and exhibitions, and socialization to stakeholders and the community [6].

Food has primary, secondary, and tertiary functions. Primary function of food is to fulfill the needs of nutrition to support growth and development of human body while secondary function of food is related to good appearance and taste of the food. Increasing of public awareness about the importance of healthy life encourages the emergence of food tertiary function promoting the physiological functions for human body, for example lower cholesterol level

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and lower blood sugar level. Food can play a role in certain physiological function because it contains bioactive compounds that help the body's metabolism. Food that fulfills the tertiary function is known as functional food. Functional food is foods/beverages with health benefits that exceed its nutritional content. There are several criteria that must be met so that a type of food can be categorized as functional food. Those are nutritional (highly nutritious), sensory (good taste, attractive appearance), and physiological (providing beneficial physiological effects on human body) [7]. Consumption of functional food is believed to be able to reduce national health costs. People who consume functional food have better health status [8].

As a mega biodiversity country, Indonesia has high abundant and diverse local foods which are potential as sources of functional food, either to be utilized in the food industry or for direct consumption and being part of the daily menu. Some of these foods contain bioactive compounds which are beneficial for human body physiologically, although their benefits may not be recognized by the people because they are not familiar with functional food concept. Generally, the concept of functional food is relatively new in developing countries, so that public awareness about benefits of this kind of food is still low [8].

In order to obtain functional food benefits, the consumption of foodstuffs containing various bioactive compounds must be increased. Lack of knowledge about functional food and its health benefits is the reason for the low popularity of functional foodstuffs like adlay. Therefore, this review will summarize the bioactive compounds and health benefits of adlay, as well as the potency of its local genetic resources at East Kalimantan.

GENETIC RESOURCES OF ADLAY IN EAST KALIMANTAN

Adlay is a cereal crop originated from Asia and has spread throughout the world. Traditionally, people from various tribes in Kalimantan have been familiar with adlay as food ingredient [9, 10], medicinal plant [11, 12] or material in making crafts, such as necklaces, bags, bracelets, and scarves [13]. Local adlay cultivars were found in Kutai Barat and Kutai Kartanegara Regencies [6, 10], where adlay was usually not intensively cultivated. This method of planting is common in all regions in Indonesia because adlay is still an alternate crop planted side by side with the main crop in rice fields, fields, and yards.

Traditional upland rice farmers in East Kalimantan have known adlay for a long time. Before 1980s, adlay were widespread at various regions in East Kalimantan, but then have been increasingly marginalized since the government implemented *Bimbingan Massal* (Bimas) and *Intensifikasi Massal* (Inmas) programs to achieve rice self-sufficiency through lowland rice cultivation [6]. Before the Bimas and Inmas era, farmers in East Kalimantan cultivated upland rice using shifting cultivation techniques. Usually, adlay was planted together with upland rice as a barrier [6, 10]. Then adlay seed was processed into Dayak's traditional food which served as typical/traditional dish in planting procession and harvesting procession of upland rice [6]. Adlay has cultural value for the Dayak tribe because it is widely used in traditional events [10].

Considering the social aspects of adlay for the Dayak community [6, 10, 11, 13] and the existing of various local cultivars/landraces of adlay [6, 11], it is predicted that East Kalimantan has high genetic diversity of adlay, although there are no scientific result to proof it. There are three local cultivars of adlay in East Kalimantan obtained from the seeds purification by farmers in Loa Kulu District, Kutai Kartanegara namely *jelai* PJSR 1, *jelai* PJSR 2, and *jelai* PJSR 3 [10]. Those three cultivars were used in several adlay development programs in collaboration with farmer groups and regional government in Kutai Kartanegara [6].

The oldest relative of genus *Coix* is *C. aquatica*, which is the ancestor of *C. lacryma-jobi* var. *lacryma-jobi* and *C. lacryma-jobi* var. *ma-yuen* [5]. Var. *ma-yuen* is a type of commonly cultivated adlay which is used as food and traditional medicine. On the other hand, var. *lacryma-jobi* is usually used as a raw material for making crafts because the seed shell is very hard and difficult to crack. *Jelai* PJSR 1, *jelai* PJSR 2, and *jelai* PJSR 3 are *ma-yuen* types of which the seeds can be processed into grits or adlay flour. *Jelai* PJSR 1, *jelai* PJSR 2, and *jelai* PJSR 3 from Kutai Kartanegara have similarities with several accessions of Chinese-cultivated adlay in seed color and hulled grain color [10]. *Jelai* PJSR 1 and *jelai* PJSR 3 have light brown seeds, while *jelai* PJSR 2 is dark brown. The hulled grain color of *jelai* PJSR 1 is light brown, while *jelai* PJSR 2 and *jelai* PJSR 3 are dark brown. Meanwhile, for seed size characters, these three local cultivars of Kutai Kartanegara have smaller seed than local adlay in West Java, but they were much larger than adlay cultivars in China [10].

Adlay also consists of glutinous and non-glutinous, but mostly adlay cultivars have glutinous endosperm with almost 0% of amylose content [14]. Genetic variations in various adlay accessions affected the ratio of amylose and amylopectin levels [14, 15]. The amylose content in non-glutinous adlay seed ranged between 15.9–26.4% [15] and some even reach 30% [14]. *Jelai* PJSR 1 is non-glutinous, while *jelai* PJSR 2 and *jelai* PJSR 3 are glutinous [10].

Kutai Kartanegara is currently on a leading position in the development and utilization of adlay local cultivars in East Kalimantan. *Jelai* PJSR 1, *jelai* PJSR 2, and *jelai* PJSR 3 are still cultivated although in a small scale. Various postharvest products of adlay, such as grits, adlay flour, and various foods made from it are still being produced, although in limited quantities, by farmers who have initiated the genetic purification and farming system of adlay local cultivars in Loa Kulu District. As one of genetic conservation efforts based on legal protection, in 2019 *jelai* PJSR 1, *jelai* PJSR 2, and *jelai* PJSR 3 have been registered as local varieties from Kutai Kartanegara by Center for Plant Variety Protection and Agricultural Permits (PPVTPP).

BIOACTIVE COMPOUNDS AND HEALTH BENEFITS OF ADLAY SEED

Bioactive compounds in food have received high attention because of their health benefits. These compounds can be classified as nutrients, such as carbohydrates, proteins, lipids, vitamins, and minerals, as well as non-nutritional substances, such as phenolic compounds and flavonoids. In traditional Chinese medicine, adlay seed has been used for thousands of years to treat various diseases, including cancer, hypertension, immunological disorders, arthritis, and diarrhea, and stimulate the function of lung and spleen [3].

Adlay seed can be processed into grits or flour which is rich in starch and protein. It is gluten-free, so it can be developed into various gluten-free products for people with celiac disease [16]. Compared to other cereals, adlay contains lower carbohydrates, but higher protein and fat [17]. Carbohydrates in adlay consisted of starch, non-starch polysaccharides, oligosaccharides, and dietary fiber. Starch is the main type of carbohydrate contained in adlay seed or grits [4]. Polysaccharides are a type of carbohydrate that cannot be digested by digestive enzymes, so they can play a role as prebiotics [18] to stimulate the growth and activity of the gut microbiota (Table 1). The balance of the gut microbiota is very important for human health and prevention of various diseases. The protein content of adlay seed range from 12.2 to 16.7%. The main protein contained in adlay seeds is prolamin known as coixin, up to 70% of total protein [4]. The high content of unsaturated fatty acids in adlay seeds, both MUFA and PUFA, indicates that adlay is potential to be an alternative source of edible oil [1]. Adlay seed also contains vitamin E consisted of four tocopherols (alpha, beta, gamma, and delta) and three tocotrienols (alpha, gamma, and delta), with the most dominant are gamma-tocopherol and gamma-tocotrienol [1].

Adlay seed also contains various non-nutritional bioactive compounds, including polyphenols, flavonoids, phenolic acids, lactam, and spiroenone. These compounds play roles in many bioactivities as antioxidant, anticancer and antiproliferation, anti-inflammation, immunological modulation, antidiabetic and anti-obesity, gut microbiota modification, and lipid profile regulation (Table 1).

CHALLENGES AND STRATEGIES FOR UTILIZATION OF ADLAY LOCAL CULTIVARS AS FUNCTIONAL FOOD

In East Kalimantan, farming system of adlay is still using traditional method/technology with low production. Usually, it is planted as a barrier in upland rice cultivation. Generally, yield is not a commercial produced, but for personal or community need related to its status as traditional food. In addition, compared to other cereals, the price of adlay seed is more expensive due to higher production costs (longer crop life and difficult postharvest processing). Therefore, even though it is available in the market, its demand is low.

Adlay is an underutilized cereal, mainly due to lack of information about its health benefits, so socialization needs to be carried out. Socialization targets include community as consumers, farmers as producers, and government as stakeholders and policy makers. Support from the government will trigger the farmers to plant and develop adlay, so the products become available in the market at affordable prices. People who have been aware of the food benefits are excited to consume it as substitute for similar food stuffs that are more commonly consumed.

Support from local government plays a very important role in the development of local cultivars of adlay. The support can be implemented in regulatory support as the legal basis for implementing local cultivar development, collaborating with related agencies in terms of research, plant improvement, marketing, processing industries etc., as well as budget allocation for research and assistance for farmers and product processing entrepreneurs. The improvement of Rojolele rice, a local rice cultivar from Klaten Regency, could be a role model of local government support for successful development of local varieties [30]. Rojolele is superior local rice in Klaten Regency, however its late maturity time and long stem are needed to be improved. Local government program has been successfully done to shorten this rice variety. Local Government of Klaten established the upstream to downstream

TABLE 1. Bioactive compounds and health benefits of adlay seed.

Bioactivity	Bioactive compounds	Major finding	References
Antioxidant	Polyphenols	Positive correlation between TPC and antioxidant activities	[19]
	Flavonoids	Positive correlation between TFC and antioxidant activities	[19]
	FOS	FOS have antioxidant activity equivalent to vitamin C and does not have a cytotoxic effect	[20]
	Polysaccharides	The water-extractable polysaccharides in adlay (Coixan A, Coixan B, and Coixan C) are useful as antioxidant	[18]
Anticancer and antiproliferative	Phenolic acids	Caffeic acid and chlorogenic acid significantly suppressed the growth of gastric cancer cells	[21]
	Lactams and spiroenone	Lactams and spiroenone of adlay bran ethanolic extract play roles in suppressing the growth of breast cancer cells	[22]
	Polysaccharides	CP-1 polysaccharide extracted from adlay seed can inhibit proliferation and induce apoptosis in non-small cell lung cancer (NSCLC)	[23]
	Fatty acid	Adlay seed oil has anticancer activity against T24 cells (bladder cancer cells in humans) by inhibiting cell proliferation, which has a positive correlation with the ratio of palmitic acid and linoleic acid to oleic acid	[2]
Antiinflammation	Flavonoids	Flavonoids in adlay bran contribute to its anti-inflammatory effect, in which the most active compounds were tangeretin, nobiletin, and p-hydroxybenzoic acid	[24]
Immunomodulatory	Polysaccharides	Polysaccharide AAP-1 and AAP-2 are potential in modulating the immune system	[18]
Gut microbiota modification	Polysaccharides	Polysaccharide extract from adlay seed can increase the growth of two probiotic bacteria (*Lactobacillus casei* and *Bifidobacterium bifidum*)	[25]
	Polyphenols	Polyphenol extract of adlay can be a useful dietary supplement in the imbalanced gut microbial ecology	[26]
Antidiabetic and anti-obesity	-	Adlay seed has low glycemic index (55) and low glycemic load (9)	[27]
	Dietary fiber, polyphenols	Water extract of adlay seed reduce obesity and fat accumulation	[28]
Lipid profile regulation	Polyphenols	Polyphenol extract of adlay is significantly effective in decreasing the serum level of total cholesterol and LDL-cholesterole, while increasing HDL-cholesterole and antioxidant capacity	[29]

TPC = total phenolic compounds, TFC = total flavonoid compounds, FOS = fructo-oligosaccharides.

institutions for managing Rojolele rice, built rice markets and supporting economic centers, and cooperated with related agencies for plant development and marketing. One of the marketing strategies is using special packaging with brand of Klaten and promoting it as Klaten's iconic souvenir. The comprehensive steps taken by Local Government of Klaten can be a reference model in the development of adlay local cultivar at East Kalimantan. Government's support is provided in all related aspects, from exploration potential cultivars, identification followed by genetic purification and improvement if necessary, conservation based on legal protection and plant development, including support for the seed production, postharvest industry, and product marketing. Therefore, local government needs to collaborate with relevant agencies. Those are local development planning agency, local department of agriculture, local research and development agency, assessment institute for agricultural technology, seed certification agency, and universities, as well as invite and engage with investors to involve at downstream agroindustry of adlay.

For Dayak community, adlay has cultural value for traditional rituals. The Dayak community has been familiar with adlay in farming system, postharvest processing, and its use as a type of local food, even though it is not a staple food. Traditional food is highly influenced by the eating habits of the community, and integrated into the sociocultural system of an ethnic group in a certain area. Today, many traditional foods are increasingly marginalized because of less of prestige compared to modern food, as well as processed foods of adlay in Dayak community. The traditional foodmade from adlayare porridge, alcoholic drinks made from fermented adlay seeds, and various snacks. These traditional foods currently become less known and are unfamiliar among the younger generation.

Food is an important product in the tourism industry, and there is a mutually beneficial relationship between traditional food and tourism industry. Traditional food can be used to attract tourists, and vice versa, the tourism industry can be used to promote traditional food [31]. Adlay and its processed products as local food and traditional foods that are closely related to the Dayak tribe are potential to be developed as part of cultural tourism for the Dayak tribe. An attractive and innovative appearance and various types of preparations are important to increase the attractiveness of adlay traditional foods.

Postharvest technologies are needed to improve the prestige and image of local and traditional foods, so they could compete with modern foods. In Loa Kulu District, Kutai Kartanegara Regency innovations in name, form/display, presentation trend, and type of processed food from adlay seeds are still being improved by farmers initiating the purification and farming system of adlay local cultivars. Processed foods of adlay that have been produced, including "rice" porridge, "green bean" porridge, *tape*, caramel popcorn, rice roll, pudding, *dodol*, and various cakes made from adlay flour as a substitute for wheat flour or white rice flour. Beside the diversification of the products, appearance and serving of the foods were made as attractive as possible with modern touches, so it is expected to increase consumer interest. Along with processed foods, grits and adlay flour are other products of adlay that can be used as souvenirs because they are durable and easy to carry. In Kutai Barat Regency, there are institutions which have produced, packed, and sold grits and adlay flour as iconic souvenirs of Kutai Barat.

Processing of food into flour is one way to increase the utilization of less popular local food. Flour is the simplest semi-processed form of adlay seed which can increase the variety of uses. In the form of flour, adlay seed is more resistant to be stored, easier to be applied in various types of food, suitable to be mixed (made composites), and convenient to be enriched with nutrients (fortified). Thus, they can become raw materials in functional food industry. Adlay flour will encourage the emergence of various food products, and will support food diversification program.

Adlay is a non-conventional sources of flour which is still underutilized, with unique and promising characters to be developed in various products [32]. Adlay flour contains 57,8% starch [33], which is a fraction of energy-rich starch, potential to be applied in healthy food products that require high stability during storage [34]. Compared to corn or potato starch, adlay starch contained lower amylose, higher crystalline structure, slower retrogradation rate, and lower digestibility [34].

Conventional adlay flour has coarse texture and less bright color. The flour quality can be improved by fermenting adlay seeds before processed into flour. Fermentation of adlay seeds with cellulolytic bacteria and lactic acid bacteria can reduce carbohydrate content, increase protein and dietary fiber content, and improve the quality/texture of adlay flour [35]. Fermentation of adlay seeds with 1% yeast solution for 72 hours can improve the quality of adlay flour, where the flour can substitute wheat flour for making cookies, and become composite of wheat flour (30:70 ratio of adlay:wheat) in manufacturing white bread [36]. The same composition was also used by Andoy *et al*. to make adlay composite flour and all-purpose flour in saltine biscuits manufacture [37].

CONCLUSION

Adlay seed is a type of functional food which beneficial for human health. The bioactive compounds contained in adlay seeds are carbohydrates in form of oligosaccharides and polysaccharides, proteins with the main component of prolamin/coixin, fats which are dominated by MUFA and PUFA, vitamin E (tocopherols and tocotrienols), phenolic compounds, flavonoids, phenolic acids, lactam, and spiroenone. These bioactive compounds provide beneficial physiological effects for the human body, because their role as antioxidant that can prevent or treat diseases associated with oxidative stress, such as cancer, cardiovascular disease, and dementia. These bioactive compounds can also reduce the risk of coronary heart disease because of its hypo-cholesterol properties, reduce the risk of type II diabetes because of its hypoglycemic role, become anti-inflammatory agent, and play a role in immunomodulation system.

Socialization about the health benefits of adlay seed needs to be carried out to open awareness and increase knowledge, so that it will increase consumption. Socialization targets include the community as consumers, farmers as producers, and the government as stakeholders and policy makers.

High genetic diversity of adlay local cultivars in East Kalimantan is a huge potential for exploration and identification of superior and specific cultivars according to community preferences, so they are potential to be developed. Local government support plays a very important role in the development of local cultivars of adlay. Comprehensive support is needed starting from exploration potential cultivars, identification followed by genetic

purification and improvement if necessary, conservation based on legal protection, plant development including support for the seed production, postharvest industry, and product marketing.

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