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Edible flowers of Southeast Asia and their possible methods of processing

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled "Edible flowers of Southeast Asia and their possible methods of processing" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 15/04/2022

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Abstract

This paper deals with edible flowers in the Southeast Asian region as a reaction to their increasing popularity among consumers. Totally 60 different species of plants whose flowers are suitable for human consumption were listed, together with their common processing methods. The most abundant family of plants with edible flowers is the Fabaceae family (23.3 %), followed by the Zingiberaceae family (10 %) and the Malvaceae family (8.3 %). The most frequent use of flowers is as a vegetable, which occurs in 45 % of the described species. Flowers are most commonly eaten raw, which is the case for 76.6 % of the described species, or cooked, which is true for 66.6 % of the described species. Additionally, three representatives, namely *Arenga pinnata*, *Moringa oleifera*, and *Sesbania grandiflora*, were described in greater detail as multipurpose trees that are also suitable for agroforestry systems. Subsequently, edible flower processing methods were described, namely: fermentation, pickling, cooking, natural drying, hot air drying, microwave drying, freeze drying (lyophilization), low temperature storage, and high hydrostatic pressure technology. For each of the processing methods, the sensory characteristics of the processed flowers were evaluated.

Key words: Edible flowers, Southeast Asia, Food processing, Sensory analysis, Shelf life

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List of the abbreviations used in the thesis

ASEAN	Association of Southeast Asian Nations
EF	Edible Flowers
MHz	Megahertz
Pa	Pascals
PROSEA	Plant Resources of South-East Asia
SE Asia	Southeast Asia
NUS	Neglected and Underutilised Species
W	Watt
μm Hg	Microns of Mercury

1. Introduction

Edible flowers have been used in human diets since ancient times (Rop et al. 2012; Pires et al. 2019). The area of edible flowers is attracting growing attention due to globalisation and the increasing awareness of consumers, which shifted towards a higher demand for functional food (Cunningham 2015; Matyjaszczyk & Śmiechowska 2019). Edible flowers have many uses in agriculture, human diet, gastronomy, cosmetic industry, pharmacology, and medicine (Kaisoon et al. 2012; Lim 2014a; Pires et al. 2017). Although many species of edible flowers are consumed raw, edible flower processing is responsible for food safety, shelf life, marketability, and sensory properties of the flowers; therefore, processing methods are an important part of this work.

This paper provides an overview of edible flowers of Southeast Asia, together with their local names, utilisation, and the processing methods applied to them the most. The aim is also to describe three species of edible flowers that represent multipurpose trees and can thus find use in agroforestry systems. Furthermore, this work explores the association of processing methods and their effect on the sensory parameters of processed flowers.

The present study is expected to contribute to our understanding of edible flowers, as well as their importance in diets and their main shortcomings. The findings of edible flower species can be applied to further studies investigating their health impacts on human bodies and, after evaluation, integrating them into the international bodies that are responsible for their official recognition (Rodrigues et al. 2017; Demasi et al. 2021b).

Edible flowers are usually defined as species that do not endanger the consumer when consumed (Santos & Reis 2021). Food processing is the act of performing mechanical or chemical operations on food to modify or preserve it (Shantamma et al. 2021). Lastly, according to Demasi et al. (2021), sensory analysis uses human senses (sight, smell, taste, and touch) for the purposes of evaluating various products.

2. Aims of the thesis

A detailed overview of plant species of Southeast Asia whose flowers can be used for human consumption will be executed. The possibilities of processing edible flowers will be analysed, and the properties of the final product will be described, with an emphasis placed on sensory properties. According to predetermined parameters, several suitable representatives of the listed species will be selected and described in further detail.

3. Methodology

The literature was retrieved from Science Direct, Scopus, Web of Science, Taylor & Francis, and Google Scholar databases. In addition, reliable websites such as FAOSTAT, ASEAN and PROSEA were used.

Based on the data found and considering the predetermined criteria, a table of Southeast Asian plant species whose flowers can be used for human consumption was compiled. Predetermined criteria were as follows. The species selected had to be native to Southeast Asia or be pantropical with an unknown location of origin. However, the pantropical species must have been described in the literature as already naturalized in the Southeast Asian region. Further, the literature had to exclusively state that the flower species were edible and used for specific purposes in the human diet. The species can therefore be incorporated into the human diet. Conversely, for example, species considered edible but used only for medical purposes were not included in the table.

Verification of selected species was carried out using the International Plant Name Index and Plant Resources of South-East Asia databases. Percentage data calculations were obtained using Microsoft Excel.

In addition, three representative species were selected from the executed table. These species must meet the criterion of being multipurpose trees. They also must have agronomic and agroforestry potential.

The processing methods were chosen in such a way that traditional methods could be compared with modern processing approaches.

4. Literature review

4.1. Southeast Asia

Southeast Asia (SE Asia) is a geographical subregion in the southeast of Asia, the region includes south-eastern China, south-eastern India, and northwest Australia. This area is geographically divided into mainland SE Asia (Cambodia, Laos, Myanmar, peninsular Malaysia, Thailand, and Vietnam) and maritime SE Asia (Brunei, East Malaysia, East Timor, Indonesia, Philippines, and Singapore) (ASEAN 2020).

SE Asian climate is mostly tropical, humid and rainy throughout the year, with abundant rainfall. Most regions of SE Asia have dry and wet seasons due to seasonal changes in winds and monsoons. The area of SE Asia is one of the world's most vulnerable to climate change (OECD 2017). Climate change will have a major impact on agriculture, affecting irrigation systems, water quality and supply as a result of rainfall and water flow changes (Mishra et al. 2021).

The region's main agricultural form is wet rice cultivation (FAO 2020). Other food crops, such as maize, cassava and pulses, are often grown in dry areas where there is too little water for planting rice (FAO 2020). Most rice producers are smallholders, farming in rural areas (Davila et al. 2018). According to the World Bank (2021), the average of people living in rural areas in Southeast Asian countries is 56 % as of 2020 (the lowest value is in Malaysia with 23 %, the highest values are in Cambodia with 76 %). Agriculture is the main source of income in all countries of the region, except for Brunei and Singapore. However, agricultural employment has been declining. The proportion of the gross domestic product (GDP) produced from agriculture has decreased as the ASEAN countries' economies have been reformed toward growth in industry and services, most notably in Indonesia, Malaysia, and Thailand (ASEAN 2020).

4.2. Food security in Southeast Asia

Food security is a multidisciplinary concept that covers several fields. The FAO definition of food security from the World Food Summit (1996) is as follows: "Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life".

It would be an extensive chapter to describe the food security of each SE Asian country individually. Therefore, the issue will be described through the lens of the Association of Southeast Asian Nations (ASEAN), whose members are the countries of SE Asia, namely: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam (ASEAN 2020). ASEAN is an organisation that unites the countries of SE Asia. It has several goals, such as economic growth; social progress; promotion of peace and justice with human rights and effective legal system; mutual assistance in common interests (social, cultural, technical, academic, ...); support growth in agriculture, industry and trade; and close cooperation and development of good relations with the member states (ASEAN 2020). Part of this agenda is food security, which ASEAN has given great importance to in recent years. This is due, among other things, to globally volatile food prices, growing populations, and global warming (Chandra & Lontoh 2010). These factors greatly affect international commodity trade and place citizens in a precarious situation.

Although statistical trends are not uniform across ASEAN member states, the prevalence of undernourishment, often used as an indicator of food security, is declining. Brunei (< 2.5 %), Malaysia (3.2 %), and Singapore are considered food-secure states, as their prevalence of undernourishment values is less than 5 %. In Lao PDR (5.3 %), the Philippines (9.4 %), Vietnam (6.7 %), Thailand (8.2 %), and Myanmar (7.6 %), the prevalence of undernutrition is steadily declining, but still falls short of food-secure countries. In the remaining member states, the prevalence of undernourishment fluctuates and is not constant due to several factors, such as macroeconomic conditions in Indonesia (6.5 %) or national political problems in Cambodia (6.2 %) (OECD 2017). These data may not include the COVID-19 pandemic, as the most recent data on FAOSTAT are from the 2018-2020 period (FAOSTAT 2020).

Rice accounts for the largest share of caloric intake in this area. The share of rice in the diet of poor rural areas can be up to 70 % (OECD 2017; Mishra et al. 2021). When comparing the SE Asian region to other developing countries, the importance of cereals is noticeably high (OECD 2017). Thus, rice plays a crucial role in food security, and even the slightest fluctuation in its price or supply can have critical impact on millions of households. Due to this dominance of rice, ASEAN has decided that the primary goal of the food security agenda will be self-sufficiency in the rice producing sector, in as many member states as possible (ASEAN 2020; Belesky 2014; Mason-D'Croz et al. 2016). Given that most of the rice production in SE Asia is grown by smallholder farmers, they are the focus group (Asian Development Bank 2011; OECD 2017). Additionally, the poorest household are spending approximately 60 % of their income on food and 20 % on rice, making this group prone to any risks or sudden changes (Davila et al. 2018).

In general, there is a trend that poorer households have a higher proportion of rice in their diet (Asngari et al. 2020). On the contrary, households with higher incomes are subsiding rice (Asngari et al. 2020). Therefore, it can be assumed that the higher the per capita income, the more diversified the diet will be. Myanmar has the highest average rice consumption value (63 %), followed by Vietnam (54 %), while in Thailand, we observe "only" 40 % (United Nations 2009; OECD 2017; Friend et al. 2019). As a result, the average SE Asia household receives 30-50 % of its protein alone from rice.

The mentioned dominance of rice in the agricultural sector of SE Asia poses several risks. In the case of monocultures, it is necessary to consider the possibility of outbreaks of disease or pest infestation. Rapid spread would result in low incomes and catastrophic effects on household food security, especially in poor production areas. This would have the effect of worsening the already often poor nutrition.

4.2.1. Malnutrition

Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients (WHO 2022). In the context of SE Asia and this thesis, this problematic includes undernutrition, a phenomenon that can result in stunting, underweight, or lack of micronutrients.

The low dietary diversity in SE Asia, which can be characterized by households consuming excessive amounts of cereals (mostly rice) at the expense of other crops such as vegetables, fruits, or legumes, results in several health problems or risks. Evidence suggests that regions with high rice consumption have a higher rate of stunting and underweight, especially in rural areas (Li et al. 2020). Stunting is caused by the irregular diet of children (under the age of 5) associated with a lack of nutrients (Asian Development Bank 2011). The number of these cases also reflects the food security situation, as it also includes the individual's health parameters. We see the highest stunting numbers for the year 2020 in Lao PDR (30.2 %) and Cambodia (29.9 %), while the smallest share is in Thailand (12.3 %) and Malaysia (20.9 %), again, these numbers may not reflect the COVID-19 pandemic (FAOSTAT 2020).

Despite the fact that the malnutrition values have improved radically (around 20 % in 1990, now a maximum of 9.4 in the Philippines for 2020), it is still assumed that twice as many people are on the verge of malnutrition (FAOSTAT 2020, OECD 2017). Of course, this problem has many factors, but a diversified and sustainable diet plays an important role, especially for the poorest households in rural areas.

4.2.2. Role of NUS in food security

In response to the previous text, which outlined the issue of low diversity of commercial agricultural crops in SE Asia, this chapter will address neglected and underutilised crops (NUS). NUS are crops that, despite their local use, are often forgotten in commercial agricultural practices, are rarely the subject of research, or are otherwise omitted by agricultural actors (Padulosi et al. 2021). This is due to several shortcomings of the NUS, such as: lower economic competitiveness combined with limited consumer awareness, little experience with agricultural and processing practices, or lower crop yields (Li et al. 2020; Padulosi et al. 2021). The vast majority of EF fall under the NUS.

There are several benefits associated with NUS. The most important properties for this work are their ability to improve the food security status of individuals and households (Massawe et al. 2015). When NUS is included in local agricultural practices, the diversity of cultivated crops increases. Assuming that NUS species are of local origin, it can be argued that due to their adaptation to biotic and abiotic factors of the locality, these species are more resistant to stress or cyclical phenomena that threaten production (Mayes et al. 2012; Padulosi et al. 2021). Compared to rice monoculture, for example, which is exposed to high risks of pest infestation or climate change, NUS species are more resilient and do not pose a high risk of losing production in such cases (Mayes et al. 2012). Furthermore, NUS increases the availability of production in theory, as these species are said to be predominantly essential in marginal areas and therefore more locally available (Massawe et al. 2015; Li et al. 2020). This factor is one of the dimensions of food security. Availability, often linked to the local market, can directly affect a producer's income (Li et al. 2020). Therefore, NUS species are critical for resource-poor farmers, located mainly in marginal areas, since they are the main growers of these species (OECD 2017).

Crop diversification will increase the nutritional values that would often be lacking in monocultures. Therefore, diversified systems are ahead of commercially grown crops, since NUS species often have essential micronutrients (minerals, vitamins) and a good macronutrient profile (energy, fats, proteins, carbohydrates) compared to a poor diet (Mayes et al. 2012; Li et al. 2020). Many plant species with edible flowers contain bioactive components and essential elements, carbohydrates, and amino acids in the flowers themselves or in other edible parts of the species, which gives EF an attribute that improves the health of their consumers (Lim 2014b). Therefore, the incorporation of NUS species may be an appropriate strategy to combat malnutrition and various other non-communicable diseases (Jones & Sanyang 2009; Li et al. 2020; Padulosi et al. 2021). It is important to note that the nutritional and other values of all NUS species vary from one to another.

Despite these named advantages that NUS species have, it is necessary to select species based on existing (or cultural) agricultural practices, which are dominant in SE Asia. It is not possible to reorient such a deep-seated system in a short time and, therefore, it is necessary to approach changes in agricultural practices systematically (Li 2018). Therefore, local accessibility and adaptability are also one of the FAO criteria in their Future Smart Food program, which, among other aspects, focuses on the incorporation of NUS species into agriculture (Li 2018). The remaining criteria for a suitable NUS specie are to be nutrient-dense; climate-resilient; and economically viable (Li 2018).

4.3. Role of edible flowers

Edible flowers are deeply rooted in cultures across continents. Historical sources mention them as part of art (when they were used mainly for ceremonial events), natural medicine, and also in the diet, where they had a decorative flavouring function (Mlcek & Rop 2011; Rodrigues et al. 2017; Pinakin et al. 2020). EF are those species that do not endanger the consumer when consumed (Santos & Reis 2021). As such, EF have a long tradition in most of the SE Asian countries where they represent an almost daily part of the diet (Rodrigues et al. 2017). Precisely due to the long tradition of EF consumption, knowledge about them is passed on from generation to generation in native communities of marginal areas (Santos & Reis 2021). This passed on knowledge plays a crucial role in rural communities, as it identifies the species of plants whose flowers are safe to eat, together with which parts of the flower are used (petals, flower buds, whole inflorescence) and, if the flowers are not eaten raw, introduces the necessary processing methods (Singh et al. 2019; Santos & Reis 2021). Therefore, some authors argue that EF play a vital role in some SE Asian tribal communities not only for their nutritional values but also for their sociocultural and spiritual attributes (Santos & Reis 2021; Kumari et al. 2021).

Flowers are grown not only for ornamental reasons, but also for their health, nutritional, cosmetic, and culinary properties (Singh et al. 2019). In the food industry, their function to enhance the sensory quality of a given food seems to predominate. This is one of the main reasons why EF are mostly eaten raw, as even minimal processing can compromise their sensory properties (Matyjaszczyk & Śmiechowska 2019). Furthermore, EF are used in a variety of dishes such as salads, soups, different fried foods, desserts, pickled dishes, jams and many others (Lim 2014b; Singh et al. 2019). Globalisation is helping EF with modern utilisation, with many manufacturers seeing EF as a value-adding ingredient, especially in gourmet cuisine (Fernandes et al. 2020a). However, there are also products such as sweets, ice creams, juices, and many others, where EF are added in varying proportions to improve the sensory or nutritional properties of a given product (Mlcek & Rop 2011; Santos & Reis 2021). The most frequent sources of EF are producers themselves, local markets, some specialised stores, and online retailers (Fernandes et al. 2020a).

Edible flowers have varying popularity depending on the country and continent. However, some authors agree that EF are in greater demand in SE Asia (Fernandes et al.

2020a; Kumari et al. 2021), although the exact reasons why this is the case are not stated. Globalisation not only contributes to greater consumer awareness, but also reveals a greater consumer demand for locally grown produce, which is often considered healthier (Mlcek & Rop 2011; Fernandes et al. 2020a). Furthermore, EF are often referred to as functional food (Kumari et al. 2021; Demasi et al. 2021a). Although functional food does not have a universal definition, a common interpretation of the term is "processed food that can prevent disease and/or has health benefits along with good nutritional values" (Arihara 2014). Additionally, Lara-Cortés et al. (2013) developed the term "floriphagia", the consumption of fresh edible flowers having functional characteristics and/or therapeutic or sensory properties associated with their taste. All of these characteristics support the theories of the rising popularity of EF and their agronomic potential.

4.3.1. Edible flower market

Due to the greater (traditional) use of EF in marginal areas, the literature agrees that EF are potentially more important in the local economy compared to international trade (Fernandes et al. 2020a; Falla et al. 2020). Together with the predictions, it can be assumed that EF producers should find a larger range of buyers mainly due to the increasing popularity of this product (Rodrigues et al. 2017; Fernandes et al. 2020a; Mlcek et al. 2021). However, at this point in time, it is difficult to say exactly how the EF market will develop in Southeast Asia. In a number of European countries, we are seeing an increase in popularity of EF, mainly due to the aforementioned trend of locally grown crops (Fernandes et al. 2020a; Demasi et al. 2021a). In addition, EF have a certain novelty factor that, according to surveys, plays a major role, despite the fact that EF have been consumed in many European flowers in the distant past (Fernandes et al. 2020b; Kumari et al. 2021). It is not clear, therefore, whether the development of the EF market in Europe can be regarded as a model example in a situation where EF are a frequent part of the diet but are not a product that is often sought out.

Data published from customer preferences surveys can be used to successfully introduce marketing strategies of EF or expose them to the wider market. Not surprisingly, the most important factor influencing the purchase of EF is their sensory properties (Kelley et al. 2002; Chen & Wei 2017; Rodrigues et al. 2017; Singh et al. 2019; Santos & Reis 2021). In terms of sensory attributes, taste and appearance (especially colour) are most important (Rodrigues et al. 2017; Fernandes et al. 2020a). Yellow, orange, and blue flowers are the most popular (Fernandes et al. 2020a). The curiosity mentioned above is often associated with the sensory attributes of EF, together with the fact that consumers perceive EF as exotic (Rodrigues et al. 2017). Other factors to which buyers attribute importance are the nutritional values and health benefits of EF (Chen & Wei 2017; Singh et al. 2019). These factors again vary depending on the country where the survey is conducted. In Portugal, factors such as product novelty and buyer curiosity played a dominant role, while curiosity and health benefits were prominent in Taiwan (Chen & Wei 2017; Fernandes et al. 2020a). Scepticism among customers was caused by the possible toxicity of the flowers, followed by fear of chemical contamination because of pesticide use (Singh et al. 2019). It is also necessary to mention that the respondents of most consumer preference surveys conducted on EF were younger people with higher levels of education, which biases the survey results if we want to attribute them to a whole society.

Some countries grow EF on commercial bases. This is most often done in combination with the production of cut flowers, medicinal plants, or salad crops (Anca et al. 2013). Diversifying production in the case of EF seems to be a good idea, as it is a seasonal production that can be harvested within a certain time frame (Anca et al. 2013; Kumari et al. 2021). The regions with the highest production of EF are Europe, North America, and the Asia-Pacific region (Fernandes et al. 2017; Kumari et al. 2021). The Asia-Pacific region (Australia, China, Japan, India, New Zealand, and the rest of Asia-Pacific) accounts for the largest market share (Fernandes et al. 2020a; Kumari et al. 2021). Commercial production of EF is more expensive compared to other productions, mainly due to the need for organic production methods (Anca et al. 2013; Kumari et al. 2021). Many sources recommend organic production due to the high possibility of contamination of EF by pesticides or other agrochemicals in commercial agriculture (Rop et al. 2012; Pinakin et al. 2020; Demasi et al. 2021a). This is also a major reason why it is not recommended to purchase EF from florists or nurseries, as this increases the possibility of contamination of the product (Rop et al. 2012; Santos & Reis 2021). Considering the limited knowledge of good farming practices, it is clear why some sources cite this business as not as profitable.

4.3.2. Nutritional and health benefits of edible flowers

While the negative health impacts of current industrial food systems are evident, less is known about the positive health impacts that alternative food and farming systems, specifically diversified agro(organic) systems, can have. These systems have great potential to improve household diets and nutrition, thereby reducing the risk of malnutrition and diseases associated with it (Frison & Clément 2020). Due to the great diversity of the different species of EF, their health-promoting properties cannot be generalised, thus those properties on which the literature often agrees will be described.

The nutritional value of EF varies depending on the species and part of the flower. The flower can be divided into 3 basic parts: petals, pollen, and nectar. Each part has different nutritional values, which apply for most species, but these values cannot be generalized. Pollen is considered to be a good source of protein, carbohydrates, amino acids, saccharides, saturated and unsaturated lipids, carotenoids, etc. However, the amount of pollen in the flower is small and the taste is not considered to be distinctive (Parkinson & Pacini 1995; Weber 1996). The next part is nectar. It is described as a sweet liquid that contains a balanced amount of sugars (fructose, glucose, and sucrose), protein, amino acids, lipids, organic acids, etc. (Mlcek & Rop 2011). The last part are the flower petals, which are attributed to a good proportion of vitamins, minerals, and antioxidants (Mlcek & Rop 2011; Kaisoon et al. 2012). The colours of the flowers are mainly determined by the content of carotenoids and flavonoids among other chemicals (Friedman et al. 2010).

The main component is water (about 70-90 %), the second main nutrient is saccharides (Pires et al. 2019). The lipid content of EF is variable from 0.1 to 10 % on a dry matter basis (Rivas-García et al. 2021) . According to some authors, the protein composition is similar to the lipid content (Pires et al. 2017). In addition, González-Barrio et al. (2018) examined the fibre composition of flowers. The fibre concentration varies within a wide range between 6-55 %. Therefore, the overall concentration is comparable to that of other plant foods (Fernandes et al. 2018).

Minerals are the micronutrients with the highest variability. Rop et al. (2012) revealed that EF are an exceptional source of phosphorus and potassium. The vitamins found there are among the areas that have not been explored well. Certain water-soluble forms of vitamins have been identified in some petals, such as vitamin C and B2 (Lara-

Cortés et al. 2013). Vitamins A and E have also been discovered in them (Mlcek & Rop 2011).

Flowers also contain several bioactive compounds. Thanks to these, EF have bioactive potential, including antibacterial, antioxidant, and anti-inflammatory abilities. Based on this, researchers suggest that flower extracts can be used as functional foods in the prevention of chronic diseases such as cancer, obesity, and diabetes (Kumari et al. 2021; Matyjaszczyk & Śmiechowska 2019).

4.3.3. Shortcoming of edible flowers

Legislative shortcomings are probably the most significant obstacle to the consumption, production, and trade of EF. No international body (e.g. European Food Safety Authority, Food and Drug Administration, United Nations Food and Agriculture Organization) has published an official and up-to-date list of edible flowers (Rodrigues et al. 2017; Fernandes et al. 2020; Demasi et al. 2021b). Thus, there is a lack of safety guidelines for the consumption of EF, such as a recommended daily intake, which is not established for most species. However, it is difficult to provide such information given the number of edible flower species. This is essential for NUS species, as most of them are species collected in the wild where there is a risk of misidentification, toxicity, or other adverse effects on human health.

Allergies are also frequently mentioned in the literature as a potential threat. Despite the large number of allergens that EF may possess, the risk generally applies mainly to those individuals who are allergic to hay and/or pollen or suffer from asthma (Wetzel et al. 2010). Such people could experience an allergic reaction after eating EF. There is also concern that EF may be a source of foodborne diseases, as they are in many cases eaten raw, without more thorough post-harvest processing to maintain their sensory properties (Matyjaszczyk & Śmiechowska 2019). A related problem is that of external contamination, which can occur throughout the supply chain, mainly from sources such as irrigation, chemical contamination during production, or airborne contamination during transport and delivery of EF.

Probably the factor that most disrupts the market for EF is their short freshness period. Freshness is directly related to the sensory qualities of EF and, in general, the fresher the flowers are, the greater their market value. Thus, when edible flower producers do not have sufficient post-harvest treatment options, such as chilling or drying, they only have a given period of time to sell the flowers at the best prices (Fernandes et al. 2019). In this case, the production of EF will not be very profitable, and its full agronomic potential will not be realised. Post-harvest methods can also prevent the aforementioned food-born diseases, which will increase the quality and safety of the product (Wetzel et al. 2010). These are the main reasons for finding suitable post-harvest methods for EF that do not compromise too much on the sensory qualities of the flowers, prolong their shelf life and, in the best case, are also usable by marginal communities.

4.3.4. Edible flowers used in Southeast Asia

Edible flowers have been part of the human diet for centuries and so their uses are wide-ranging (Lim 2014b). Flowers are part of the diet of Southeast Asia and, as such, in addition to their nutritional and sensory benefits, they have a certain degree of cultural significance. The flowers can be eaten raw or fresh as a garnish in salads, for example. Depending on their use, flowers fulfil different functions in the diet, from the sensory and nutritional functions mentioned above, to health-promoting functions, where local communities believe in their health benefits (Cunningham 2015; Chouni & Paul 2017). The use of one edible flower species may vary depending on the local community of people who use it. Flowers can be eaten raw, cooked, lightly fried in batter, while some species are steamed or added to various oils as condiments or sweeteners. The term "as a vegetable" (used in Table 1) describes a use where flowers are considered to represent the same position in the diet as any vegetable. Additionally, EF are becoming popular with gourmet chefs as a value-adding ingredient.

The following Table 1 demonstrates the types of edible flowers in SE Asia along with their traditional uses and processing methods.

Table 1. Selected edible flower species in SE Asia

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
1.	*Anethum graveolens*	dill	Indonesia: ender Laos: phak s'i	Apiaceae	SE Asia	condiment, pickles	hot-air drying, sun-drying, raw	2; 14
2.	*Aponogeton lakhonensis*	NA	Cambodia: sbai mung Vietnam: choi	Aponogetonaceae	Indonesia, Thailand, Cambodia, Myanmar	as a vegetable	raw	2; 12
3.	*Arenga pinnata*	sugar palm	Cambodia: chuĕk' Thailand: chok	Arecaceae	Cambodia, India, Thailand, Vietnam	sweetener, vinegar	flower juice crystallization, fermentation	10; 11
4.	*Telosma cordata*	Chinese violet	Thailand: bunga siam, salit	Asclepiadaceae	South China, Thailand, Vietnam, Malaysia	as a vegetable, soups, stir fries	boiling, frying, raw	2; 55
5.	*Ageratum conyzoides*	chick weed	Indonesia: ki bau Thailand: ya saap Vietnam: cỏ hôi	Asteraceae	pantropical	condiment	palm oil infusion	46; 47
6.	*Cosmos sulphureus*	yellow cosmos	Indonesia: kembang goyang Philippines: cosmos	Asteraceae	pantropical	garnish, salads	raw	41; 48
7.	*Dendranthema indicum*	Indian chrysanthemum	Indonesia: sruni alas Thailand: benchamaat suan	Asteraceae	Taiwan, Indonesia, Vietnam	garnish, curries, pickles	boiling, pickling	26; 27

(continued)

Table 1. Selected edible flower species in SE Asia (continued)

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
8.	*Impatiens balsamina*	garden balsam	Indonesia: pacar banyu, pacar air	Balsaminaceae	SE Asia	curries, salads	frying, boiling, raw	30; 47
9.	*Bombax ceiba*	cottonwood	Malaysia: kapok Thailand: ngui	Bombacaceae	SE Asia	condiment, curries, soups	drying, pickling, raw	7
10.	*Mesua ferrea*	iron wood	Malaysia: tapis Philippines: kaliuas	Calophyllaceae	Thailand, Indochina, the Philippines, Malaysia, Myanmar	garnish, salads	raw	39; 49
11.	*Lonicera confusa*	honeysuckle	Vietnam: kim ngân dại	Caprifoliaceae	south China, Vietnam	as a vegetable, garnish	boiling, raw	47; 50
12.	*Combretum indicum*	rangoon creeper	Indonesia: ceguk Laos: dok ung Vietnam: cha ro	Combretaceae	pantropical	as a vegetable	steaming, raw	39; 47
13.	*Cheilocostus speciosus*	crepe ginger	Laos: uang Malaysia: teng Thailand: kushta	Costaceae	Malaysia, Indochina, Papua New Guinea	garnish, salads	raw	51; 52
14.	*Bauhinia purpurea*	orchid tree	Myanmar: swèý-tau ni Philippines: alibang-bang	Fabaceae	South China, Myanmar, the Philippines	as a vegetable, curries, pickles, condiment	boiling, steaming, pickling	28; 29; 32; 46
15.	*Bauhinia variegata*	mountain ebony	Indonesia: tali kancu Thailand: pho-phe	Fabaceae	SE Asia	salads, side dish, stir fry	boiling, frying, raw	2; 3

(continued)

Table 1. Selected edible flower species in SE Asia (continued)

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
16.	*Butea monosperma*	flame of the forest	Indonesia: palasa Cambodia: chaa	Fabaceae	Myanmar, Thailand, Papua New Guinea	colourant, beverages, as a vegetable	boiling, drying, soaking, raw	16; 17
17.	*Canavalia gladiata*	sword bean	Philippines: habas Thailand: thua-phra	Fabaceae	pantropical	side dish, condiment	steaming	2; 15
18.	*Cassia fistula*	golden shower	Indonesia: klobob Malaysia: bereksa Thailand: khuun	Fabaceae	pantropical	soups, curries	boiling, frying	24; 25
19.	*Clitoria ternatea*	butterfly pea	Thailand: ang chan Vietnam: dau biec	Fabaceae	pantropical	colourant, salads, stir fries	boiling, frying, sun drying	39; 40; 41
20.	*Erythrina variegata*	coral tree	Laos: do:k kho Malaysia: dedap	Fabaceae	pantropical	as a vegetable	boiling	32; 47
21.	*Lablab purpureus*	hyacinth bean	Indonesia: komak Vietnam: dâu van	Fabaceae	India, SE Asia	as a vegetable	boiling	2; 8
22.	*Psophocarpus tetragonolobus*	winged bean	Indonesia: kecipir Philippines: kabey Thailand: thua-phu	Fabaceae	pantropical	salads, as a vegetable	boiling, frying, raw	22; 23
23.	*Senna siamea*	Siamese cassia	Myanmar: mezali Laos: khi ‘lek	Fabaceae	SE Asia	soups, curries, as a vegetable, pickles	boiling, frying, pickling	39; 40; 41

(continued)

Table 1. Selected edible flower species in SE Asia (continued)

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
24.	*Senna timoriensis*	limestone cassia	Myanmar: taw-mezalie Malaysia: beksa	Fabaceae	Myanmar, Thailand, Malaysia	as a vegetable	boiling	47; 53
25.	*Sesbania grandiflora*	hummingbird tree	Malaysia: turi Philippines: diana Vietnam: so dũa	Fabaceae	SE Asia	curries, soups, salads, as a vegetable	boiling, steaming, frying, raw	7; 24; 30; 39; 40
26.	*Sesbania javanica*	marsh sesbania	Cambodia: snaô Vietnam: dien dien phai	Fabaceae	SE Asia	as a vegetable, soups, curries, stir fries	boiling, frying, raw	8; 39; 47
27.	*Tamarindus indica*	tamarind	Indonesia: asam Cambodia: ampil Vietnam: trai me	Fabaceae	pantropical	condiment	boiling, pickling	2; 18
28.	*Hemerocallis fulva*	orange daylily	Thailand: dtô n-jam-chàai Vietnam: hoa hiên	Liliaceae	Taiwan, Vietnam	as a vegetable, thickener, soups	drying, boiling, raw	24; 33
29.	*Woodfordia fruticosa*	fire-flame bush	Malaysia: silu, sidawayah	Lythraceae	Indochina, Thailand, Malaysia	colourant, condiment	sun-drying, boiling	7; 2
30.	*Abutilon indicum*	country mallow	Indonesia: kecil Philippines: palis	Malvaceae	pantropical	curries, salads, garnish	boiling, raw	32; 33
31.	*Hibiscus mutabilis*	Chinese rose	Indonesia: waru landak Malaysia: botan	Malvaceae	SE Asia & China	colourant, salads	boiling, raw	33

(continued)

Table 1. Selected edible flower species in SE Asia (continued)

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
32.	*Hibiscus rosa-sinensis*	Chinese hibiscus	Thailand: chaba Laos: may	Malvaceae	pantropical	salads, garnish, chutney, colourant, pickles	boiling, raw, pickling	32; 33
33.	*Hibiscus syriacus*	common hibiscus	Malaysia: gumamelang asul	Malvaceae	Malaysia	colourant, garnish	boiling, raw	34
34.	*Hibiscus tiliaceus*	beach hibiscus	Indonesia: waru Vietnam: bụp tra	Malvaceae	pantropical	garnish, curries	raw, boiling, frying	33; 35
35.	*Aglaia odoratissima*	NA	Indonesia: tanglu Malaysia: kasai Thailand: prayong	Meliaceae	Brunei, India, Indonesia, Thailand, Malaysia,	condiment	sun-drying	2
36.	*Azadirachta indica*	neem tree	Cambodia: sdao Indonesia: mimba Thailand: sadao	Meliaceae	SE Asia	as a vegetable, salads, soup	steaming, boiling, raw	8; 33; 36
37.	*Broussonetia luzonica*	birch flower	Philippines: himbaba-o, babayan	Moraceae	the Philippines	as a side dish, vegetable, stir fry	boiling, frying	2; 21
38.	*Moringa oleifera*	drumstick	Indonesia: kelor Thailand:marum	Moringaceae	pantropical	as a vegetable, soups	boiling, drying, raw	4; 5; 6
39.	*Musa acuminata*	edible banana	Cambodia: chec Indonesia: pisang batu Thailand: kluai	Musaceae	SE Asia	as a vegetable, soups, curries	boiling, frying, raw	2; 19; 20

(continued)

Table 1. Selected edible flower species in SE Asia (continued)

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
40.	*Musa balbisiana*	plantain	Indonesia: pisang Thailand: kluai	Musaceae	SE Asia	soups, stir fries, curries	boiling	2; 17
41.	*Syzygium aromaticum*	clove	Indonesia: bunga cengkeh	Myrtaceae	Indonesia, Malaysia	spice, condiment	drying	33; 37
42.	*Nelumbo nucifera*	lotus	Malaysia: seroja Cambodia: chhu:k Laos: bwá	Nelumbonaceae	SE Asia	stir fries, garnish	frying, raw	40; 41
43.	*Nymphaea nouchali*	star lotus	Malaysia: telepok Philippines:talailo Vietnam: súng	Nymphaeaceae	SE Asia	garnish, salads, as a vegetable	boiling, raw	2; 38
44.	*Forsythia* × *intermedia Zabel*	forsythia	NA	Oleaceae	SE Asia	garnish, salads, curries	drying, boiling, raw	33
45.	*Jasminum sambac*	Arabian jasmine	Malaysia: melati Cambodia: molih Vietnam: lai	Oleaceae	Myanmar, Malaysia, Indonesia	condiment, fragrance	sun-drying, soaking	8; 39
46.	*Osmanthus fragrans*	sweet osmanthus	Laos: guìhuā Thailand: kue ho	Oleaceae	SE Asia	condiment, jams, deserts	raw, boiling	54; 26
47.	*Monochoria hastata*	hastate-leaved pondweed	Indonesia: bia-bia Cambodia: chrach Thailand: phaktop	Pontederiaceae	SE Asia	as a vegetable, salads	raw	9; 2

(continued)

Table 1. Selected edible flower species in SE Asia (continued)

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
48.	*Gardenia jasminoides*	common gardenia	Laos: ph'ud Philippines: rosal Thailand: phut	Rubiaceae	pantropical	sweetener, salads, deserts, syrups	drying, raw	8; 33
49.	*Ixora chinensis*	Chinese ixora	Indonesia: siantan Thailand: kem	Rubiaceae	pantropical	salads, stir fry	frying, raw	33; 40; 41
50.	*Ixora coccinea*	jungle flame	Indonesia: merah Thailand: khem	Rubiaceae	pantropical	condiment, salads, garnish	sun-drying, raw	33; 40; 42
51.	*Ixora javanica*	jungle geranium	Indonesia: soka Malaysia: siantan Thailand: khem	Rubiaceae	Thailand, Malaysia, Indonesia	as a vegetable, soups	boiling, raw	33; 42
52.	*Neolamarckia cadamba*	burflower-tree, kadam	Malaysia: laran Thailand: krathum	Rubiaceae	Indochina, Thailand, Malaysia, New Guinea	condiment, soups	boiling	13; 2
53.	*Madhuca longifolia*	butter tree	Indonesia: vippa Thailand: chettu	Sapotaceae	SE Asia	sweetener, candy, jam, juice, beverages, flour	sun drying, fermentation, raw	1; 2
54.	*Typha orientalis*	Asian bulrush	Indonesia: heikre Vietnam: bồn bồn lá rộng	Typhaceae	SE Asia	spikes as a vegetable, pollen in flour and porridge	boiling, frying, raw	8; 43
55.	*Alpinia galanga*	galanga	Malaysia: puar Philippines: palla	Zingiberaceae	SE Asia	as a vegetable, condiment	boiling, steaming, raw	30; 31

(continued)

Table 1. Selected edible flower species in SE Asia (continued)

	Scientific Name	English Name	Local Name	Family	Distribution	Traditional Use	Processing	Sources
56.	*Amomum dealbatum*	NA	Indonesia: resah, hanggasa	Zingiberaceae	Indonesia	as a vegetable	boiling, raw	28; 29
57.	*Etlingera elatior*	torch ginger	Indonesia: kantan Thailand: kaa laa	Zingiberaceae	SE Asia	condiment, as a vegetable, pickles, curries	boiling, pickling, raw	8; 39; 40; 44
58.	*Etlingera hemisphaerica*	tulip ginger	Indonesia: sikala Thailand: kaa laa	Zingiberaceae	SE Asia	condiment, curries	boiling, raw	33; 44
59.	*Hedychium coronarium*	butterfly ginger	Malaysia: suli Philippines: banai	Zingiberaceae	pantropical	as a vegetable, condiment	boiling, raw	8; 30; 33
60.	*Zingiber zerumbet*	pinecone ginger	Philippines: barik Thailand: haeo dam	Zingiberaceae	pantropical	flower buds as a vegetable	boiling	33; 44; 45

1.-(Singh et al. 2021), 2.-(PROSEA 2022), 3.-(Villavicencio et al. 2018), 4.-(Jayasri P et al. 2021), 5.-(Sahay et al. 2017), 6.-(Islam et al. 2021), 7.-(Pinakin et al. 2020), 8.-(Tanaka & Nguyen 2007), 9.-(Dipankar 2013), 10.-(Fajar Dewantara & Sinaga 2017), 11.-(Azhar et al. 2019), 12.-(Chougule et al. 2022), 13.-(Bhatt et al. 2009), 14.-(Jana & Shekhawat 2010), 15.-(Botanical Name Index 2010), 16.-(Sinha et al. 2012), 17.-(Burli & Khade 2007), 18.-(De Caluwe et al. 2010), 19.-(Fingolo et al. 2012), 20.-(Mathew & Negi 2017), 21.-(Casuga et al. 2016), 22.-(Valíček 1989), 23.-(Tanzi et al. 2019), 24.-(Kumari et al. 2021), 25.-(Singh et al. 2019), 26.-(Matyjaszczyk & Śmiechowska 2019), 27.-(Semuli 2014), 28.-(Takahashi et al. 2020), 29.-(Deb et al. 2019), 30.-(Benvenuti & Mazzoncini 2021), 31.-(Chouni & Paul 2017), 32.-(Reddy et al. 2007), 33.-(Lim 2014b), 34.-(Bost 2004), 35.-(Dane 2012), 36.-(Maisuthisakul et al. 2008), 37.-(Zhao et al. 2019), 38.-(Irvine & Trickett 1953), 39.-(Wetwitayaklung et al. 2008), 40.-(Wongwattanasathien et al. 2010), 41.-(Kaisoon et al. 2011), 42.- (Dontha et al. 2015), 43.-(Brooker et al. 1989), 44.-(Noweg et al. 2003), 45.-(Singh et al. 2012), 46.-(Li et al. 2014), 47.-(Lim 2014a), 48.-(Kaisoon et al. 2012), 49.-(Asif et al. 2017), 50.-(Chau & Wu 2006), 51.-(Voon Boon Hoe & Kueh Hong Siong 1999), 52.-(Singh 2011), 53.-(Monkheang et al. 2011), 54.-(Xin et al. 2013); 55.-(Fernandes et al. 2020b)

Table 1 shows that Fabaceae is the leading family of EF species in Southeast Asia. Of the 60 species described, 14 of them are from the Fabaceae family, which means that they occupy 23.3 % of the entire Table 1. Flowers from this family are usually used as vegetables; however, their taste is typically described as non-distinguished (Wongwattanasathien et al. 2010). The advantage of this family is that the awareness of their consumption is higher compared to the rest of the family, and therefore, consumption of flowers of this family is more frequent. The family Zingiberaceae contributes 10 % to the Table 1, and thus is the second most common family. The flowers of this family are eaten mainly raw and are attributed with characteristic taste qualities (Noweg et al. 2003). For this reason, the flowers of Zingiberaceae are mostly used as condiment in selected dishes. However, they are also known to be used as a vegetable. The family Malvaceae represents 8.3 % in Table 1. The flowers of this family are characterized by high aesthetic value (Reddy et al. 2007). For this reason, they are most often used as a garnish. To maintain their visual features, they are used raw in recipes, as processing them would affect the structure of the flowers. The diversity of utilisation of these three most frequent families reflects the wide use of EF across and within families.

The use of EF in the diet depends on the qualities of each species. In most cases, one species had multiple uses. The most common utilisation of EF is as a vegetable - this is true for 45 % of the flowers in the overview (Tab. 1). In some cases, this use overlaps with other recipes such as salads or curries. Such situations occurred when explicitly these recipes were named as staples for the species described. Furthermore, flowers are used as condiments (28.3 %), garnishes (28.3 %), colorants and pickles (each 10 %), or sweeteners (6.6 %). A single species, however, can have multiple uses, and for this reason the percentages exceed 100 %.

One type of edible flower can have multiple processing methods. However, the most common is the raw consumption of the flower (76.6 %). Other methods of processing are boiling (66.6 %), frying (28.3 %), drying (28.3 %), pickling (13.3 %), steaming (10 %) and soaking (5 %). Other processing methods have lower values and are mainly species-specific. Due to the frequent fresh consumption of the flower, strict hygiene guidelines are necessary during production and distribution, but these are published by any official authority.

4.3.5. Selected edible flowers species

The following chapter will be devoted to a more detailed description of three selected species of edible flowers, namely *Arenga pinnata*, *Moringa oleifera* and *Sesbania grandiflora*. These species can be used in agroforestry systems and are considered to be multipurpose trees. Multipurpose trees are trees that are intentionally grown and managed for multiple outputs (Martini et al. 2012). According to Withington et al. (1988), those outputs could be shade, shelter, food, fodder, fuelwood, and timber, but in some cases may improve soil fertility.

4.3.5.1. *Arenga pinnata*

According to the International Plant Name Index, *Arenga pinnata*, also know as sugar palm, is a member of the Arecaceae family. Its origin lies in an area covering South-East Asia up to north-eastwards to Japan and north-west to Vietnam and the eastern Himalayas (PROSEA 2022).

According to the Plant Resources of South East Asia (2022), sugar palm is a moderate to tall unbranched solitary palm. Trunk 10-20 m long and 30-65 cm in diameter. Inflorescence usually unisexual, pendulous, often more than 2 m long, peduncle breaking up into several flower-bearing spikes (as in Figure 1). Roots black, strong, extending far (up to 10 m and more) from the stem and going as deep as 3 m.

Figure 1. Male flower of *A. pinnata*

Source: Azhar et al. 2019

A. pinnata grows best in warm soils with maximum amount of light and abundant water supply in fertile soils (PROSEA 2022). However, it can grow under a variety of conditions, both in the equatorial and seasonal climate, from sea level up to 1400 m, on all soils that are not regularly inundated. It occurs especially in low-nutrient areas and in marginal areas, such as dried hillsides (Azhar et al. 2019). The age of the first flowering depends greatly on altitude, it is 5-7 years at the sea level and 12-15 years at altitude of 900 m (Withington et al. 1988).

In the study conducted by Azhar et al. (2019), the farmers use sugar palm mainly for increasing their income. The sap from this palm is a common product collected by farmers and then traditionally processed into palm sugar syrup for beverages. The sap is harvested when male flowers are tapped. The harvesting period of the sap is 2-3 months. One bunch of flowers can produce 3-5 litres of water per day, depending on the fertility of the sugar palm trees and the altitude levels. The productivity of the flowers increases during the harvest period and subsequently decreases as the period ends. The sap must be immediately filtered and cooked due to the acidic content. The juice is cooked for 4-5 hours to obtain the desired dark-coloured sugar.

Due to various utilisations *A. pinnata* covers, it is suitable agroforestry species, particularly planted in Sumatra (Martini et al. 2012; Barfod et al. 2015). Apart from the already described flower sap, sugar palm can be used for sago (used for example for cakes and noodles), its leaves can be used as a roofing material and fuelwood, and the trunk wood is used as a construction material (Withington et al. 1988; Barfod et al. 2015; Azhar et al. 2019). Lastly, based on the study of Withington et al. (1988), sago is harvested after more 30 years, as its harvesting requires cutting down the tree, and a reasonable harvest of flowers sap comes after 10-12 years after the palms planting. Due to this long perid of waiting for economic returns, *A. pinnata* is considered to be a long-term investment.

4.3.5.2. *Moringa oleifera*

According to the International Plant Name Index, *Moringa oleifera*, also know as drumstick, is a member of the Moringaceae family. It was introduced into SE Asia, where it also naturalized, at an early date, and is now cultivated throughout the tropics (PROSEA 2022).

According to the Plant Resources of South East Asia (2022), *M. oleifera* is a small tree or shrub that grows to 10 meters (as in Figure 2). The leaves are 30-60 cm long and have an oval shape. The flowers are bisexual and aromatic, with five unequal white petals. The tree starts to flower approximately 6 months after planting. Inside the fruit, which are up to 100 cm, there are seeds with a diameter of 1-1.5 cm (Liu et al. 2018).

Drumstick is a plant of tropical and subtropical regions. Growth of the shrub is better in lower altitudes, where it tolerates water shortages well. Therefore, low temperatures and abundant water are not suitable. It can also be grown in marginal soils, bud prefers well fertile, sandy soils (PROSEA 2022).

The flowers have a variety of nutrients like proteins, potassium, calcium antioxidants, and polyunsaturated fatty acids (Liu et al. 2018). Therefore, the consumption of the flowers contributes to a well-balanced diet (Kumar et al. 2017). The flowers are mostly consumed raw as a vegetable or are cooked to be incorporated in various recipes (Islam et al. 2021). The powder made from the dried flowers is also frequently added to porridges to enhance their nutritive values. Powder derived from flowers is also more suitable than the powder from leaves, as the flower powder maintains the original colour and appearance of the dish (Liu et al. 2018).

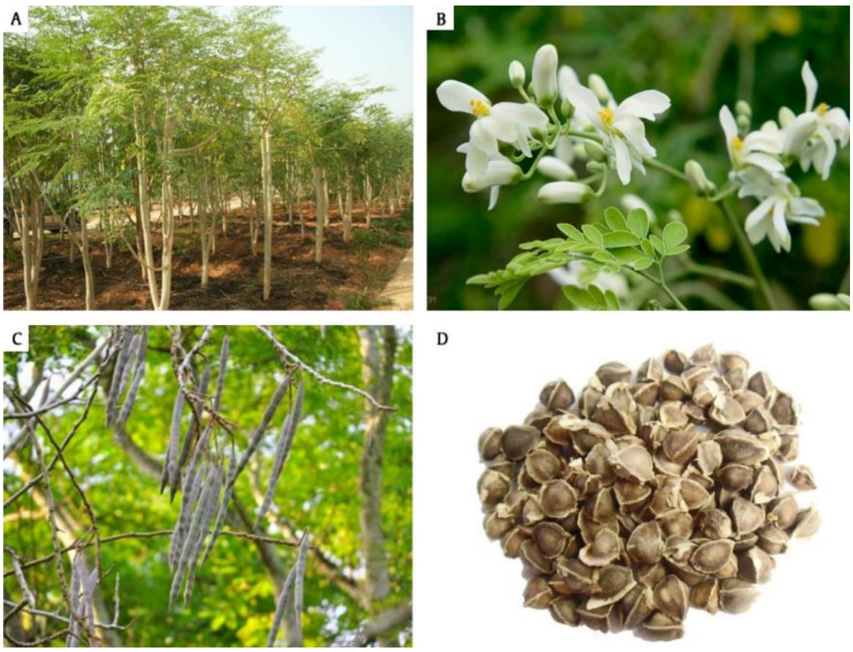

Figure 2. Whole plant, flowers, pods, and dried fruits of *M. oleifera*

Source: Liu et al. 2018

In SE Asia, the tree is mainly used as a vegetable. Leaves, fruits, flowers, and roots are edible (PROSEA 2022). Sometimes, the fruits are fried and eaten like peanuts (Withington et al. 1988). Additionally, the seeds are also used to extract edible oil used for cooking, but also for cosmetics and lubrication (Sahay et al. 2017). The bark yields fibre that can be used to produce paper and mats (PROSEA 2022). Twigs and leaves are often used as feed; however, the remaining seed cake is not suitable as feed because of its alkaloid values (Devkota & Bhusal 2020). The tree is also used as a living fence, as a shade tree (mainly in home gardens), and as a support for pepper vines (Withington et al. 1988).

According to the research by Kumar et al. (2017), *M. oleifera* fulfils many parameters to be a suitable agricultural component. The tree is fast growing, has a deep root system, mitigates climate change, and due to its uses, has an interesting economic potential. The trees are usually planted between the crops. Crop yields are increased in the field where moringa is integrated because it is rich in nutrients and its deep roots extract subsurface nutrients from the soil. In recent years, the moringa tree has become an important part of the silvo-quaculture system, mainly due to its leaves and fruits, which are a good feed for fish.

4.3.5.3. *Sesbania grandiflora*

According to the International Plant Name Index, *Sesbania grandiflora*, also known as the hummingbird tree, is a member of the Fabaceae family. Although the origin of *S. grandiflora* is not exactly known, it is considered to be native in SE Asian countries (PROSEA 2022). It is widely spread throughout the tropics from southern Mexico to South America, Hawaii, and more recently in East Africa.

According to the Plant Resources of South East Asia (2022), *S. grandiflora* is a small open tree, 5-15 m tall and a diameter of up to 30 cm, with narrow branches. Leaves deep green, 30 cm long, and 20-40 pairs of opposite leaflets. The leaflet is elliptical, obtuse at the top, about 2-3 cm long. White or deep pink to red flowers that are 7-9 cm long (as in Figure 3).

The tree is found in open fields, near roads and waterways, from sea level to an occasional height of 1,200 m in its native region. It is adapted to tropical conditions in regions with an average annual temperature of 22-30 °C and an average annual precipitation of 2,000-4,000 mm (Withington et al. 1988). It is also highly drought tolerant, withstanding dry periods of up to 9 months. The tree is highly frost sensitive. It grows in a wide range of soils, tolerating poor nutrient conditions (Lim 2014a).

According to Lim (2014), the flowers and tender pods are commonly used as a vegetable. They are incorporated into various stews, curries, and salads. The preparation of the flowers varies greatly as they can be cooked, steamed, and eaten raw. Flowers are considered to be a good source of protein. The also contain carbohydrates, calcium, phosphorus, iron, sodium, and potassium. The flowers are also known for having medical use (Shantamma et al. 2021).

It is an important source of firewood, feed, pulp, paper, food, medicine, green fertilizers, shade tree. *S. grandiflora* can be used for the restoration of eroded grassland and forest lands throughout the tropical region (Lim 2014a; Limon et al. 2016). The tree is often used as a light shade tree for companion plants, such as turmeric and ginger, and as a living support tree for climbing plants. As a Fabaceae family member, it also contributes to soil fertility with its nitrogen-fixing bacteria (Withington et al. 1988; Islam et al. 2008).

Figure 3. Close view of flower and leaf of *S. grandiflora*

Source: Lim 2014a

4.4. Processing methods applied to edible flowers

The EF have a short shelf life of 2-5 days (Kou et al. 2012). This short shelf life is due to the high water content of the flowers, which varies from 70 % to 90 % (Pires et al. 2018). The processing of EF therefore aims to preserve their freshness and visual appeal, together with the remaining sensory properties. It also helps to guarantee the quality and safety of food and achieves a longer shelf life. The loss of quality after harvesting the flowers is manifested mainly by wilting, discolouration, browning (oxidation) and subsequent loss of petals or other parts of the edible flower (Marchioni et al. 2020; Kumari et al. 2021). Currently, there are no official guidelines that describe the appropriate storage of EF, and little is known about the effects that different storage methods can have on the harvested EF (Fernandes et al. 2019). Most of the time, fresh flowers are packed in plastic boxes or bags and then sold as such in local markets (Kelley et al. 2001). However, a similar method of sale is also seen in many western countries, where flowers packaged in this way are also sold in the herb and vegetable section (Fernandes et al. 2019).

The most common methods of processing EF in local communities in SE Asia are cooking, sun-drying, pickling, or various preserving in oils (Adeyeye 2017). However, as illustrated in Table 1, EF are most often eaten fresh, without any processing. The commercial market for EF also uses refrigeration as a method of extending the shelf life of EF (Shantamma et al. 2021). Furthermore, modern processing methods, such as lyophilization, high hydrostatic pressure, or irradiation, are possible and generally credited with favourable sensory and nutritional parameters in the final products (Fernandes et al. 2019; Marchioni et al. 2021). However, whether it is refrigeration or modern processing methods, it must be said that marginal areas where EF are produced do not necessarily have the capital and energy infrastructure to actively use these methods.

This industry is particularly interested in increasing the sales of EF, both fresh and processed. In this sense, the use of innovative food preservation technologies capable of extending the shelf life of EF would bring significant economic benefits in addition to maintaining the quality of the product for a longer period of time (Takahashi et al. 2020).

The studies on the processing of EF are focused on the treatment of individual flower species. Since the structure of flowers varies depending on the species, the characteristics of the resulting processed species cannot be applied generally to EF. However, their description can at least illustrate the results to the extent that they can be applied to anatomically similar species.

As mentioned throughout the chapters, the sensory characteristics of EF are essential for their marketability. These are those qualities that are perceived by a person's sense organs. For foods, it is especially used in combination with taste, texture, astringence which is perceived in the mouth and aroma perceived in the nose (Demasi et al. 2021b). Therefore, each description of a processing method will be followed by a summary of the sensory characteristics of the EF that have undergone the method described. This information will provide details of the extent to which the processing method preserve the unique sensory attributes of the flower, thereby increasing its marketability and price.

The following part of the text will focus on methods of processing EF and the final sensory properties of the processed flowers.

4.4.1. Fermentation

Fermentation involves the use of microorganisms and enzymes to produce foods that have a different quality profile from agricultural raw materials, where the processed food extends its shelf life, inhibits spoilage and pathogenic microorganisms, and improves nutritional value (Yahia 2008). Fermented foods show an increased biological value due to the presence of bioactive components, vitamins, and microorganisms (Rezac et al. 2018). These compounds benefit human health because they increase antioxidant activity, improve digestion, and reduce diabetes and cardiovascular risk (Rezac et al. 2018; Harasym et al. 2020).

As this is one of the oldest processing methods, the costs are negligible (Adeyeye 2017). The sensory qualities of the flowers are changed mainly in terms of taste, texture and aroma. The taste of the flower after fermentation is acidic, the texture is softer and the aroma is lost (Yahia 2008). In most cases the colour fades, the shape of the flower shows signs of wilting, browning or complete separation of the flower parts (Harasym et al. 2020).

4.4.2. Pickling

It is a process of immersing food in a solution containing salt, acid, or alcohol. Pickling allows food to extend its shelf life by increasing its acidity (reducing pH), restricting the development of microorganisms (Chung et al. 2017). The health benefits of pickled foods are related to the abundance of vitamins, minerals, and antioxidants in these products (Harasym et al. 2020). Since fresh flowers are used in the pickling process, the antioxidant content and activity of these raw materials can be fully maintained; therefore, the functional properties of the EF can be maintained (Harasym et al. 2020).

Usually, no special equipment is needed. According to Adeyeye (2017), if not carefully prepared or stored at room temperature, pickled foods can be dangerous. Pickling is often combined with other methods such as fermentation, canning, or refrigeration. It can be assumed that sensory values are similar to those in chapter 4.4.1.

4.4.3. Cooking

Boiling, steaming and frying fall under this chapter. When cooking, the flower is submerged in water at the temperature at about 100 °C (Ho et al. 2000). The nutritional value of EF is significantly lost in this way (Hotz & Gibson 2007; Zhao et al. 2019). Steaming is a process in which the flowers are placed over, not in, boiling water and the hot steam cooks the food (Nakitto et al. 2015). Steaming allows foods to retain nutritional values better than when boiled in water (Nakitto et al. 2015). Frying is the process of putting foods in hot fats or oils in an open and shallow pan, browning the outside of the food, and cooking inside to the desired level of finish (Harasym et al. 2020).

The cooking methods, like previous traditional processing methods, are inexpensive (Adeyeye 2017). They can therefore be carried out on the location of EF production without major complications. These thermal processes have a significant effect on the sensory properties of the flowers. High temperatures change the texture, aroma, taste and general appearance of the flower (Yahia 2008; Zhao et al. 2019). Steaming allows foods to retain natural flavours, colours, shapes and enhances texture of the processed food (Nakitto et al. 2015).Therefore, steaming may be the most suitable cooking method in terms sensory attributes.

4.4.4. Drying

Several specific methods belong under drying. Some of these methods are according to Shantamma et al. (2021) also used for drying EF, such as sun drying, hot air drying, freeze drying, microwave drying, or approaches that combine these methods. Despite the wide range of drying methods, it is primarily a method aimed at extending the shelf life of the product, which is achieved by reducing the water content in the crop (Chitrakar et al. 2019). Drying methods use ambient temperature together with air circulation to reduce the water content of the product. Water reduction results in the prevention of microbial activity and enzymatic degradation (Fernandes et al. 2019). Furthermore, this processing method reduces the weight of the crop, which can lead to easier and cheaper storage and logistics. Drying is also one of the most widely used processing methods among rural populations producing EF (Adeyeye 2017).

4.4.4.1. Natural drying

Natural drying (includes sun drying and shade drying) is characterized by a simple method and low production cost equipment (Zhao et al. 2019). These simple drying methods can be practiced at the point of origin. However, natural drying is influenced by climate, its drying cycle is longer, and is easily affected by pollution problems, as the drying is carried out in direct sunlight. Furthermore, natural drying is susceptible to dust, insects, birds, rodents, and other infections (Zheng et al. 2015). The loss of nutrition may be high and may not meet consistent quality standards (Marchioni et al. 2021). To inhibit the growth of pathogenic microorganisms, a water activity of less than 0.86 is recommended; to prevent the growth of yeasts and moulds, a value of less than 0.62 is required (Hnin et al. 2021). Such results can be achieved with shade drying after 72 hours at the temperature of 22 °C (Fernandes et al. 2018) . Compared to other sophisticated drying methods, natural drying takes the longest time to achieve adequate results (Fernandes et al. 2018).

This type of processing requires almost no energy inputs or other costly investments. The major obstacles here are the unpredictability of the weather and the time-consuming work involved, combined with lower productivity. Despite the time constrains and risk of contamination of the flowers, natural drying methods are accessible processing method for rural communities.

4.4.4.1.1 Sensory properties after natural drying

Sensory analyses of EF processed by natural drying are not often performed. Some authors believe that flowers processed in this way are more likely to be used in baked goods, beverages, or other products where the flowers do not play a major aesthetic role (Fernandes et al. 2018). The sensory characteristics of flowers used in this way are determined in a completely different way from other processing methods, which aim to preserve the sensory profile of the flower.

Despite this, basic visual characteristics can be determined from the research by Fernandes et al. (2018), where *Centaurea cyanus* flowers were compared after different processing methods. Figure 4 illustrates the visual characteristics of *Centaurea cyanus* flowers after 3 days of drying in the shade at 22 °C compared to fresh flowers. As a result of water reduction in the flowers, the visual attributes were distorted, there was a reduction in size, and the flower acquired a wilted appearance. There appears to be some discoloration after the processing. Flowers treated with this method can be used in tea mixtures (Fernandes et al. 2018). However, the visual attributes of the flower do not correspond to its high marketability in the gastronomic sector.

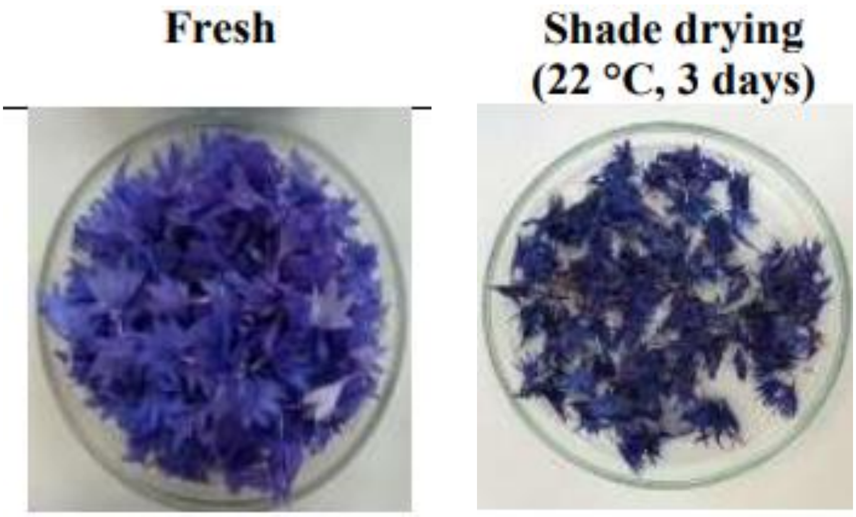

Figure 4. Visual appearance of *C. cyanus* after shade drying

Source: Fernandes et al. 2018

4.4.4.2. Convective hot air drying

The most widely used commercial processing for drying vegetables and fruits is hot air drying, in which heat is transmitted from hot air to the product by convection and evaporated water is delivered to the air also by convection (Antal 2015). Inside the dryer, hot air flows over a product belt. The heated air is used to dry the product by evaporating the water it contains (Dorozko et al. 2019). Compared to natural drying, drying with hot air is not affected by climate. This processing method is economically advantageous as minimal investment in convection dryer technology is required (Zhao et al. 2019).

The disadvantage of hot air drying is the long time that the flower is exposed to high temperatures. As a result, the flowers lose their nutritional and sensory values, thus affecting the overall quality (Reyes et al. 2010). To avoid loss of bioactive compounds, the temperature should not exceed 50 °C (Bae & Lee 2008). To inhibit the growth of pathogenic microorganisms, a water activity of less than 0.86 is recommended; to prevent the growth of yeasts and moulds, a value of less than 0.62 is required (Hnin et al. 2021). Such results can be achieved by hot air drying after 4 hours at the temperature of 50 °C with the *Centaurea cyanus* species (Fernandes et al. 2018; Hnin et al. 2021).

4.4.4.2.1 Sensory properties after convective hot air drying

With higher temperature, the size of the flower is reduced, and it loses its visual attributes. Discolouration is also a common drawback of hot air drying. According to Fernandes et al. 2018, these factors lead to certain sensory attributes of flowers that are not satisfactory. The visual appearance of fresh versus dried *Centaurea cyanus* petals is illustrated in Figure 5. Generally, all dried petals are darker and smaller than fresh petals. The petals had a different visual appearance even after short drying periods in hot air.

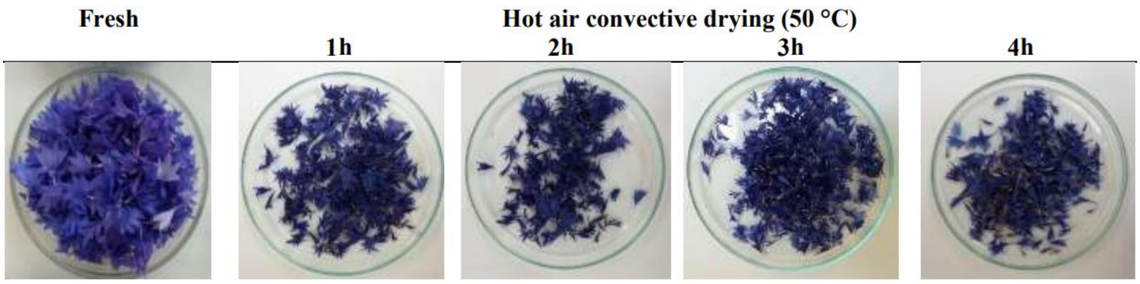

Figure 5. Visual appearance of *C. cyanus* after convective hot air drying

Source: Fernandes et al. 2018

4.4.4.3. Microwave drying

Microwaves are high-frequency electromagnetic waves with frequencies from 300 MHz to 300 kMHz (Zhao et al. 2019). The wavelength is 1 m-1 mm (Drouzaf & Schuberp 1996). It has the heating effect of dielectric induction that changes the direction of space continuously through the high-frequency electric field (Wray & Ramaswamy 2015). Polar molecules in a material vibrate at a high frequency with electromagnetic waves and generate heat (Zhao et al. 2019). During microwave heating, external temperatures are slightly lower than internal temperatures due to external water evaporation, which greatly increases the drying rates (Yan et al. 2010).

A study by Chunfang et al. (2011) investigated the different vacuum pressure (0.10 MPa and 0.08 MPa) and microwave power (200, 225, 250, 275 and 300 W) influencing the quality of dried rose. The results show that, with the increase in microwave power, drying time has decreased considerably. After a thorough evaluation of the drying temperature, time and visual parameters of the dried rose flowers, the optimum settings for vacuum microwave drying were set at 0.10 MPa, microwave power at 200 W and drying time at 80 minutes (Chunfang et al. 2011). Compared to other drying techniques, microwave drying can effectively reduce moisture content in the shortest period of time on the order of microwave drying> hot air drying>sun drying>shade drying (Li et al. 2015; Zhao et al. 2019).

A similar study was conducted by Dong et al. (2011) investigating the impact of microwave drying from the point of view of the quality of male *Eucommia ulmoides* flower tea. The functional components of the dried flowers were measured. Based on the results of sensory evaluation, the microwave output power is 560 W and the optimal duration is 2-3 minutes. Furthermore, the bioactive compounds responsible for the functional properties of the flowers were high even after treatment with an output power of 560 W. However, these results may differ for flower utilisations different from tea, as a greater emphasis is placed on the visual appearance.

Compared to hot air and freeze drying, the use of microwave drying technology in food materials is less energy and time-consuming (Menon et al. 2020). The introduction of rapid microwave drying technologies could provide promising alternatives for small farmers, as the initial investments into the technology are not that high (Orsat et al. 2008).

4.4.4.3.1 Sensory properties after microwave drying

Although flowers retain their functional profile after microwave drying, direct exposure of the flower to radiation results in a decrease in their visual values (Dong et al. 2011; Zhao et al. 2019). This leads to cell damage and subsequent charring in delicate flowers (Zhao et al. 2019). Also, according to Dong et al. (2011), the *Eucommia ulmoides* flowers had a fresh aroma, greenish colour and the structure of the flowers was also maintained after a 2-3 minutes microwave drying at the output power of 560 W.

According to Ran et al. (2021), the microwave dried roses were less bright and darker than the fresh ones (as in Figure 6). The relatively high heat efficiency of microwaves can often lead to greater colour degradation. Microwave dried roses also posses a sweet floral scent (Ran et al. 2021).

A different study conducted by Safeena & Patil (2014) investigated the application of silica gel on the flower prior to the drying procedure. The study compared sensory values of Rose flowers with and without the embedding of silica gel. The results have shown that superior quality parameters such as colour, texture and appearance were obtained when the flowers were dried and embedded into the silica gel for 2.5 minutes. Although the application of the silica gel had positive effects on all flower samples examined, its effects also varied depending on the variety of the rose in the test (Safeena & Patil 2014).

Figure 6. Visual appearance of rose after microwave drying

Source: Jinan Avan Machinery Co. 2018

4.4.4.4. Freeze drying

Freeze drying, or lyophilization, is a multi-stage food processing method that changes the moisture in raw foods from a solid to a gaseous stage. This is due to sublimation under vacuum conditions after the food has been pre-frozen. The freezing process includes three separate processes: the freezing process, the sublimation process (primary drying) and the vacuum evaporation of the unfrozen water (secondary drying) (Zhao et al. 2019). Due to the long drying time and high energy costs, freeze drying is a highly expensive method of food processing (Chan et al. 2009). In general, lyophilization minimizes loss of taste and taste components as well as bioactive compounds and reduces material shrinkage (Antal et al. 2014; Zhao et al. 2019). Because there is no liquid water and low temperatures, most microbiological reactions are eliminated and the final product is of excellent quality (Antal et al. 2014). These are the reasons why freeze drying is mainly used for products with higher added value or where it is necessary to preserve higher nutritional values (Sadikoglu et al. 2006). The marketability of freeze-dried flowers is therefore particularly high.

Chen et al. (2000) investigated the combination of parameters of freezing temperatures (-35 °C), freezing times (2 and 4 hours) and different vacuum drying temperatures (27 °C, 37 °C, 47 °C at 30–50 μm Hg) on the moisture content of the petals and stems of roses. Although the results have shown that low vacuum drying temperatures have led to the quality of flowers closer to that of fresh ones, overall recommendations for the best freezing drying conditions for the flower studied were not stated. Sirithon et al. (2012) chose a different procedure when he froze marigolds at -40 °C for 48 hours at a pressure of 140 Pa. Therefore, the parameters suitable for lyophilization of each species must be individually adapted.

To inhibit the growth of pathogenic microorganisms, a water activity of less than 0.86 is recommended; to prevent the growth of yeasts and moulds, a value of less than 0.62 is required (Hnin et al. 2021). Such results can be achieved with freeze drying after 24 hours with the *Centaurea cyanus* species (Fernandes et al. 2018; Hnin et al. 2021). The drying time required for the freezing drying process is considerably longer than that of conventional evaporative drying methods (Sadikoglu et al. 2006; Jo et al. 2008). It is therefore necessary to precisely optimise the conditions under which the product will dry best.

4.4.4.4.1 Sensory properties after freeze drying

Freeze drying should not affect the colour of processed flowers after optimising the drying parameters (Zhao et al. 2019). Light pink jasmine pigments were preserved after processing, compared to dark pigments, where a slight decrease in values was observed (Acar et al. 2011). Thus, dark-coloured flowers are more prone to discoloration than flowers with lighter pigments (Jo et al. 2008; Acar et al. 2011). Other results show that freeze drying has a strong effect on the shades of red, which change to unattractive dark red tones after processing, as illustrated in Figure 7 (Siresha & Reddy 2013). Compared to sun drying, freeze-dried saffron had lower water values, and therefore, writes Acar et al. (2011), the original flower shape is better preserved. According to Zheng et al. (2015), who studied the impact of different processing methods on *Eriobotrya japonica* flowers, freezing takes the longest time, but has the least effect on active ingredients and retains the original fragrance, colour and shape of the flowers to a large extent. The results also indicate that water evaporation helps to maintain the original flower size (Jo et al. 2008; Hnin et al. 2021). Thus, there is a reduction in water, but the size of the flower remains similar.

Although the initial investment and operational costs are high, many advantages can be repaid by the high costs of freeze drying, such as quality, storage costs, transportation, and shelf life of flowers (Zhao et al. 2019).

Figure 7. Visual appearance of rose after freeze drying

Source: Siresha & Reddy 2013

4.4.5. Low temperature storage

Temperature is a leading environmental factor affecting the development of food quality (Demasi et al. 2021b). Cool temperatures will slow down the process of senescence and blossom deterioration (Shantamma et al. 2021). Reduced respiration under cold conditions prevents rapid tissue breakdown and wilting (Fernandes et al. 2019). The enzymatic activities associated with these processes, together with the development of microorganisms attacking the flower structures, are also delayed (Shantamma et al. 2021). This puts low temperature storage at the front of post-harvest methods for extending the freshness of EF commercially, however, because of the energy supply it is hardly affordable for rural communities (Demasi et al. 2021b).

The most suitable temperature to minimize the development of bacterial colonies in EF was set at 4 to -18 °C. According to Kelley et al. (2021), who studied EF of *Viola tricolor*, *Tropaeolum majus*, *Borago officinalis*, and *Phaseolus coccineus*, these species can be effectively stored for 1 week at temperatures ranging from -2.5 to 10 °C with acceptable results. *Viola tricolor*, *Tropaeolum majus*, and *Borago officinalis* have shown excellent results even after two weeks of storage at 0 to 2.5 °C. *Phaseolus coccineus* began to deteriorate and lose its sensory properties after one week of storage at 0 to 10 °C. This indicates that the same storage methods have different effects on the flowers of different species. Similar results were described by Demasi et al. (2021), where the optimal temperature for the storage of EF was set at 4 °C for 7-14 days, depending on the flower species stored. The described species stored in this condition corresponded to marketable quality, which is essential information for the EF market.

Freezing is also a part of low temperature storage. Freezing, as well as the temperatures described above, slows down physiological activities, but the effectiveness of the fight against microorganisms increases due to the formation of ice crystals, which also mechanically cause the destruction of microorganisms (Demasi et al. 2021b; Shantamma et al. 2021). To improve the quality of EF even more during the freezing method, it is recommended to blanch the flowers to destroy the microorganisms and bacteria already present (Xin et al. 2013; Shantamma et al. 2021). According to Xin et al. (2013), freezing should not significantly alter the nutritional profile of EF; however, pretreatment with blanching can cause a decrease in the nutritional values of the flowers, together with sensory effects where the visual aspect of the flower is disturbed.

4.4.5.1. Sensory properties in low temperature storage

Research by Demasi et al. (2021), where sensory parameters of 17 different edible flowers were monitored, showed that flowers respond differently to storage at low temperatures. The parameters that were determined for this sensory analysis (such as taste, aroma intensity, specific floral aroma and chewiness, among others) reached different values for each of the samples. *Rosa canina* at a storage temperature of 4 °C achieved a shelf life of up to 14 days, together with good results in terms of aroma and intensity. Similarly, *Salvia pratensis* is well marketable as it did not lose its sensory properties significantly after a period of 7 days at 4 °C. However, *Allium ursinum* after the same storage conditions is attributed with a strong aroma but a bland taste. These facts indicate that storage at low temperatures affects the sensory parameters depending on the species under study.

Visual changes in flower storage at low temperatures cause weight reduction (Marchioni et al. 2020). According to the findings of Marchioni et al. (2020), the weight reduction after 6 days (T6) at 4 °C was 15.7 % for *Ageratum houstonianum* (A), which also showed negative results with a clear browning. For *Tagetes lemmonii* (B), the weight reduction after 6 days is 9.5 % (illustrated in Figure 8). In *T. lemoni* loss of some petals can be observed, but differences in storage time of 2 (T2) and 6 (T6) days in this species are not very noticeable. In summary, different temperatures can improve the quality and appearance of different types of EF, and by reducing storage temperature, increase the shelf life of some types.

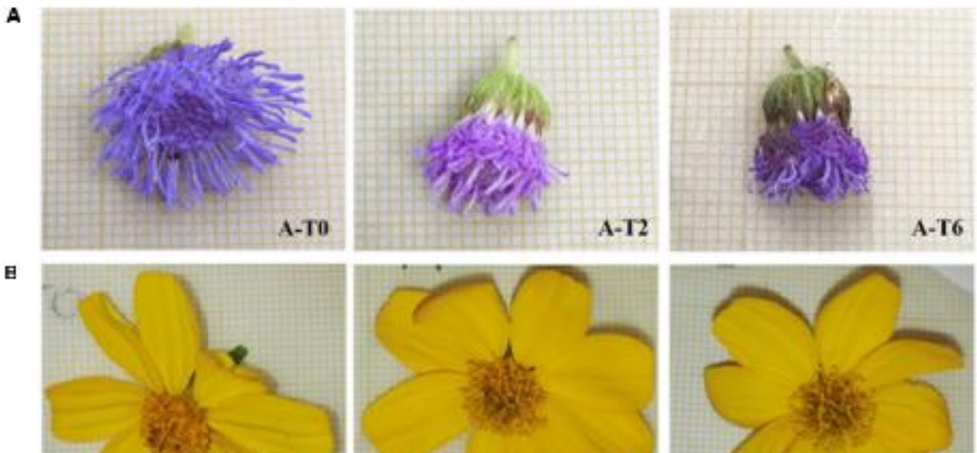

Figure 8. Visual appearance of EF in cold temperature storage

Source: Marchioni et al. 2020

4.4.6. High hydrostatic pressure technology

Currently, consumers are demanding higher standards of food safety and nutrition, especially those that play a special role in human health (Zhao et al. 2019). Therefore, in order to preserve the nutritional values as effectively as possible, non-thermal processing methods have been developed (Matyjaszczyk & Śmiechowska 2019). Although it can produce small amounts of heat, the increase in temperature does not reach the level of the traditional heating process and can be cooled by a cooling system (Bello et al. 2014). Food processed with this technique not only maintains nutritional and sensory qualities, but also provides the necessary effect of enzyme deactivation and prevents the development of microbes (Polydera et al. 2003).

High hydrostatic pressure technology uses water and liquids as a medium for transferring pressure (Zhao et al. 2019). Under pressure of 100–1000 MPa, packaged foods are processed for a certain period of time, thus changing some macromolecular structures in foods, such as enzyme inactivation, starch gelatinization and protein denaturation, and eliminating microorganisms at room temperature (Chawla et al. 2011). At the same time, certain small molecules in foods such as polyphenols and vitamins are not affected (Zhao et al. 2019). As a result, high hydrostatic pressure technology can maintain the best taste, colour and nutrients of food, along with other sensory and functional properties (Fernandes et al. 2017; Zhao et al. 2019).

Fernandes et al. (2017) studied the effects of high hydrostatic pressure treatment on camellia, cornflower, borage, and pansies flowers. The study focused on the appearance, biological activity, and microbial content after the flowers were processed and stored at 4 °C. The corn flower showed a good appearance after 100 MPa/5 min treatment, but the shelf life was not extended. In contrast, the storage time of pansies was extended to 20 days at a storage temperature of 4 °C (untreated to 6 days), after 75 MPa/5 min of treatment. Although flower response to this technology varies based on species, a treatment of 75 MPa/5-10 min seems to be promising in terms of preservation time.

Although this technology produces flowers with high marketability, it is not suitable for rural communities in SE Asia. The equipment is expensive, flowers need to be packed in an airtight container first, and the technology is also often combined with low temperature storage, which adds to already high energy costs (Fernandes et al. 2017; Shantamma et al. 2021).

4.4.6.1. Sensory properties after high hydrostatic pressure

Treatment with high hydrostatic pressure does not cause significant changes in aroma, taste, or other sensory characteristics, but its effects depend on pressure, temperature, and time (Fernandes et al. 2017). If very high pressure is used, colour changes (browning) may occur along with cooked aspects, protein denaturation and softening, along with other changes (Polydera et al. 2003; Fernandes et al. 2017). Nevertheless, high pressure, if under low or medium temperature, has limited effects on pigments, therefore the vibrant colours of the flowers can be maintained (Oey et al. 2008). Reversely, high temperatures and high pressures lead to significant colour changes (Fernandes et al. 2017). The visual properties of pansies and camellias after different high hydrostatic pressure settings are illustrated in Figure 9.

Regarding textural changes, it is related to changes in pressure itself and cell walls, since this technology causes cell destruction (Fernandes et al. 2017). On the contrary, the high hydrostatic pressure process does not change the flavour, because the structure of small flavour molecules is not directly influenced by high pressure (Oey et al. 2008).

In conclusion, the extent of cell disturbance in flowers depends not only on pressure and temperature, but also on the type of flower cells, each of which has different high hydrostatic pressure behaviours (Fernandes et al. 2017). Therefore, it is necessary to evaluate each flower individually and based on that, design suitable processing parameters.

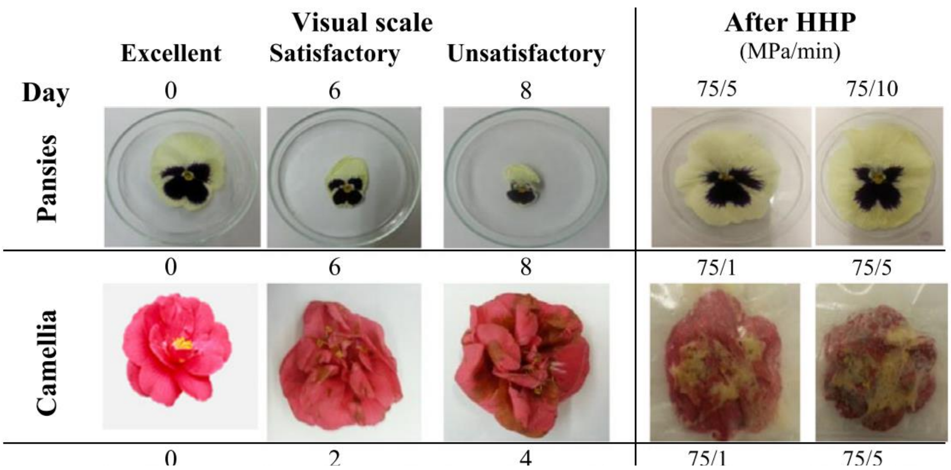

Figure 9. Visual appearance of EF after high hydrostatic pressure

Source: Fernandes et al. 2017

4.4.7. Assessment of the processing technologies

Some processing technologies can be used without compromising the physicochemical properties of EF and extending their shelf life. However, after the technologies were applied, each flower showed different behaviours. The biggest dilemma in selecting the best processing technology is that combining good flower marketability with good sensory characteristics and economic viability is very challenging.

Modern methods such as freeze drying, or high hydrostatic pressure have excellent results in terms of sensory and nutritional preservation (Oey et al. 2008; Acar et al. 2011). The processed EF then have good commercial potential, with the resulting product having sufficient food safety standards, nutritional values, desirable shelf life, and suitable sensory properties (Polydera et al. 2003; Antal et al. 2014). However, the costs of these processing methods in terms of energy demand and the required facilities are very high, and therefore their implementation in rural or marginal areas is not feasible (Chan et al. 2009; Shantamma et al. 2021).

Post-harvest treatments of low temperature storage and microwave drying require less investment than those described above (Orsat et al. 2008; Demasi et al. 2021b). Processed flowers in microwave drying lose some sensory properties and nutritional value, but the products still have a certain level of marketability (Safeena & Patil 2014). The shelf life of flowers processed this way is also considerably extended (Dong et al. 2011). Low temperature storage is a post-harvest method that can extend the shelf life of flowers by up to a week without significantly compromising the sensory properties of the flower responsible for its fresh appearance (Demasi et al. 2021b). The shelf life of the flowers is thus not significantly prolonged (Marchioni et al. 2020; Demasi et al. 2021b). Furthermore, low temperature storage requires a constant supply of energy, unlike microwave drying, which requires energy only during the actual processing of the flowers (Menon et al. 2020).

Thermal processing of natural and convective hot air drying are one of the most abundant methods of processing EF in rural and marginal areas of SE Asia (Zheng et al. 2015). The convection drying method requires minimal investment in the construction of the dryer itself and possibly a motor responsible for air circulation (Zhao et al. 2019). Flowers processed by these methods have similar sensory and nutritional values, whereby convection drying has shorter drying times and improved sanitation as the flowers are not directly exposed to the environment (Fernandes et al. 2018). Both methods are suitable for marginal areas, but the marketability of the processed flowers is one of the lowest compared to all the methods described (Fernandes et al. 2018; Zhao et al. 2019).

Traditional processing methods such as fermentation, pickling and cooking have important local relevance. Their importance lies mainly at rural household level, since they require almost no investment (Adeyeye 2017). Flowers processed in this way are suitable for immediate consumption in the case of cooking or can extend their shelf life in the case of fermentation and pickling (Chung et al. 2017). They therefore play an important role in food security, especially at local level (Adeyeye 2017). However, they have one of the worst sensory characteristics compared to the previous methods if the sensory characteristics of the flowers alone were considered (Yahia 2008; Harasym et al. 2020). It is difficult to assess the marketability of flowers processed in this way, but it can be assumed to be one of the lowest compared to the other methods.

Therefore, the appropriate method for processing EF must be chosen based on the intended use of the flowers and the economic availability of processing technologies. If the production of EF is in rural areas where the economic possibilities are limited, traditional methods, natural drying (shade drying, sun drying) or hot air drying for would be the most suitable. Processing can thus be carried out on the place of production, but the risks and time involved must be taken into account. Flowers processed in this way will have a lower price. For areas where there is more room for investment, microwave drying or storage at low temperatures, depending on the type of flower and its use, are suggested. Here, it is necessary to have energy supply for these technologies and some maintenance skills. Flowers processed this way have higher marketability. It is expected that in commercial production of EF, the processing options are more varied, and the methods can be combined. Technologies such as freeze drying, and high hydrostatic pressure processing are economically very demanding. Flowers processed in this way have high marketability and their use is much wider than that of flowers processed by previous methods.

5. Conclusions

This bachelor thesis summarizes 60 edible flowers of SE Asia along with their uses in the human diet and their common processing methods. The most abundant family of plants with edible flowers is the Fabaceae family (23.3 %), followed by the Zingiberaceae family (10 %) and the Malvaceae family (8.3 %). Frequent use of flowers is as a vegetable, which occurs in 45 % of the described species. Flowers are most commonly eaten raw, which is the case for 76.6 % of the described species, or cooked, which is true for 66.6 % of the species. *Arenga pinnata*, *Moringa oleifera*, and *Sesbania grandiflora* have been described in greater detail and show multipurpose properties, making them suitable species for agroforestry systems. Furthermore, processing methods of EF were described, where sensory characteristics show different values and thus significantly affect the marketability of the flowers. Freeze drying and high hydrostatic pressure processing methods show the best sensory properties but are not applicable in rural areas, mainly for economic reasons.

The main limitation of this work lies in the lack of an accurate quantification of the costs associated with the processing methods. This results in a difficult assessment of the suitability of the processing methods. There is also a lack of calculation of the added value that edible flowers obtain after they have been processed. This information would better contribute to the assessment of marketability of the flowers.

This work could help to identify EF in the SE Asian region and thus has the potential to diversify not only diets, but also agriculture systems. This text can also be a starting point for the recognition of EF by international bodies and the compilation of a list of recognized EF suitable for human consumption. However, further research is needed to analyse the steps required to do so. Furthermore, it is important to direct research towards sensory analyses of EF so that it is easier to introduce them to the market. Last but not least, it is still crucial to study the chemical composition of edible flowers to identify the species most suitable for consumption and to analyse their health-promoting properties.

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