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REVIEW ARTICLE

Circular models from major crop by-products in Can Tho City, Vietnam

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Abstract

The study aims to evaluate the status of major crop cultivation and propose circular models for developing agricultural by-product resources in Can Tho City, Vietnam. The proposed circular model aims to limit the use of raw materials for economic activity and minimize environmental impact by reducing the reliance on the environment as a sink for waste solids and emissions. The implementation methods included collecting data from the Department of Crop Production and Plant Protection, as well as relevant document sources. The main crop groups surveyed include rice, vegetables, longan, durian, star apple, mango and jackfruit. Among them, the three crops with the largest planted area are rice, vegetables and mango, which were selected for developing the circular models. A SWOT analysis was conducted to propose four groups of economic, social and environmental solutions to support the development of a circular model for these crops. The results were compiled from interview data from 36 experts, from which we analyzed six favorable factors, five complicated factors, five opportunity factors and six challenging factors affecting the circular models. It is possible to expand the scope of research on the circularity of the proposed products and delve deeper into the technology and production processes for each product within each circular model. It is an essential foundation for developing sustainable green agriculture in the future.

Keywords: by-products; Can Tho City; circular model; major crops

Introduction

The circular economy has gained significant interest as a means to promote sustainable agricultural development. It is an inevitable trend in countries worldwide, including Vietnam. A circular economy in agriculture is defined as a closed-cycle production process, where the waste and by-products of this process are utilized as inputs for other processes through the application of scientific and technical advances, biotechnology and physicochemical technology. Agricultural production will utilize resources efficiently, minimize waste and post-harvest losses, produce safe and high-quality products and reduce environmental pollution. If implemented effectively, this activity can protect both the ecosystem and human health. According to the FAO's announcement (1), it has been demonstrated that nearly one-third of the total food produced for human consumption is lost or wasted each year, resulting in numerous economic and environmental consequences. It has also been shown that nearly 14 % of the world's food is lost between harvest and sale. Therefore, reducing food loss and waste will contribute to achieving the sustainable development goals while ensuring food security and environmental protection.

In Vietnam, the agricultural sector has long played a central role, providing food and raw materials for industrial production and agricultural exports. However, the agricultural industry faces many environmental challenges due to waste and by-products from farming and livestock activities. Each year in the Mekong Delta, Vietnam post-harvest by-products (from farming) are often available in large quantities, such as rice straw, accounting for 42.8 million tons; corn stalks, about 10 million tons; vegetables and fruits, 3.6 million tons; cassava stalks, 3.1 million tons; and other types, about 6.1 million tons. The amount of by-products from agricultural product processing includes approximately 8.6 million tons of rice husks, 3.5 million tons of sugarcane bagasse, 1.4 million tons of corn cobs, 1.3 million tons of cassava husks and other types of 2 million tons (2).

To develop agriculture and increase farmers' incomes, the Can Tho City Agriculture Department has recently actively encouraged and supported farmers in replicating and developing circular agriculture models. They also instructed people to utilize available land, water and other resources, as well as waste/by-products from farming and animal husbandry, as raw materials for new production processes. This diversifies income sources and increases income on the same productive land area (3).

The basis for selecting research subjects is Decision No. 1629/QD-UBND of the People's Committee of Can Tho City, dated July 8, 2019. The decision "Issuing a list of major agricultural products and important products that need to be encouraged and prioritized to support the implementation of

linking production with product consumption in the City." Seven major crops were selected: rice, safe- vegetables, longan, durian, star apple, mango and jackfruit. Therefore, research is urgently needed to propose circular models for developing agricultural by-product resources in Can Tho City. This activity aims to utilize Can Tho's agricultural by-product resources in the most economical and effective manner. At the same time, it also minimizes waste and post-harvest losses, creating safe, high-quality products, significantly reducing waste to the lowest level and eliminating waste that causes environmental pollution, thereby protecting the ecosystem and people's health in this area. Therefore, the study aims to properly evaluate the status of major crop cultivation, propose circular models for developing agricultural by-product resources and analyze the advantages and disadvantages of applying a circular model to agricultural by-product resources in Can Tho. It improves the value of crops, brings high economic efficiency and promotes sustainable agricultural development and environmental protection.

Materials and Methods

Secondary data collection

Data on crop cultivation and production were collected from the Department of Crop Production and Protection, Can Tho City. Statistical data and information on major crop characteristics and growing conditions from 2021 to 2023 were also collected. In addition to the natural conditions, the current socio-economic development status of the study area was also collected.

Primary data collection

Based on standard research indicators (4), a sample size of more than 30 respondents is acceptable. Accordingly, 36 experts were interviewed for the study of the Cultivation and Plant Protection Stations and the Crop Cultivation and Plant Protection Department of Can Tho City. These individuals are directly responsible for work and possess expertise in agriculture, horticulture and related fields.

Interview content includes:

- Proposing circular use directions for major crops in Can Tho City.

- Identify factors affecting the issue of bringing the circular model into practical production:

+ Strengths: favorable factors and motivating resources contribute to better development.

+ Weaknesses: unfavorable factors and inappropriate conditions that limit development.

+ Opportunities: directions that need to be taken to optimize development, expected results to be achieved, cooperation opportunities and support policies.

+ Challenges: factors that have the potential to create bad results, unexpected results, or limit or eliminate development.

Methods of synthesizing and processing data

Synthesize and verify the results from the interview questionnaire regarding the current model's benefits and the challenges it poses for economics, society and the environment. The information and data collected through the interview questionnaire were processed using Excel for evaluation and description in tables and charts.

SWOT analysis

SWOT is a method of structured planning and evaluating any process, person, project, industry, or business on these four parameters. It encompasses both detailed and broad analyses of internal and external factors to assess feasibility and success.

The SWOT matrix was developed by Humphrey (5). SWOT (strengths, weaknesses, opportunities and threats) analysis is a framework used to develop a strategic plan. A SWOT analysis evaluates both internal and external factors, as well as current and future potential. In this study, a SWOT analysis is employed to propose solutions that enhance the efficiency of circular models when implemented in Can Tho City, considering local conditions. The resulting information can be systematically presented in the form of a matrix; different combinations of the four elements of the matrix can help determine long-term strategy.

Accordingly, SWOT analysis is performed according to the following steps:

Step 1: Identify the object to analyze, in this case, the circular model for critical crops in Can Tho.

Step 2: Identify core strengths (S), weaknesses (W) opportunities (O) and threats (T), leading to analysis based on facts, perspectives and new ideas.

Step 3: By analyzing strengths, weaknesses, opportunities and threats, it is possible to determine the impacts of implementing the proposed model, thereby devising effective strategies. Solution strategies to make the most of strengths, seize an opportunity, improve those weaknesses and deal with risks:

- Combine S-O to use strengths to exploit external opportunities.

- Combine W-O to overcome weaknesses and exploit external opportunities.

- Combine S-T to use strengths to cope with external threats.

- Combine W-T to overcome weaknesses and reduce external threats.

Step 4: From the solution strategies, draw appropriate solutions and divide them into solution groups: economic, social, environmental and policy.

Results and Discussion

Status of agricultural production in the study area

Agricultural production in Can Tho City has undergone a dramatic transformation towards concentrated commodity production, following prescribed standards and the diversification of crops and livestock. The City's agricultural production aims for green, modern and comprehensive growth to increase added value and adapt to climate change and adverse conditions. Currently, Can Tho City has formed many effective models and implemented linkages, promoting mechanization and applying technical advances in farming and animal husbandry. It helps improve production efficiency and protects both the environment and public health (6).

Due to urbanization and industrialization, Can Tho's agricultural land declined from 115430 ha in 2008 to 112380 ha in 2021. The agricultural sector must promptly innovate to improve and stabilize agricultural production in response to the new situation. What is remarkable now is the need for synchronous solutions to promote the development of effective farming models associated with good product preservation, processing and consumption. The City's Agriculture sector strives to reach a total rice production area of 206720 hectares, with a total output of more than 1.24 million tons. The area planted with vegetables and short-term industrial crops reached 15588 hectares, with an output of 170480 tons. The area planted with fruit trees reached 24320 hectares, with an output of 165825 tons. The aquaculture area reached 8500 hectares, with total aquaculture and exploitation output reaching 216750 tons. The total herd of pigs is 130000 and the poultry herd is 2 million, with the production of live meat of all kinds reaching 35500 tons. It will bring the Gross Regional Domestic Product (GRDP) in the city's agriculture, forestry and fisheries sectors to 2.85 % (6).

Can Tho City set a target for 2021-2025, the area of cultivation, aquaculture area and the number of livestock facilities certified for Good Agricultural Practices (GAP) to strive to increase by 5-10 %, 100 % of agricultural, forestry and fishery production and business establishments are certified to meet food safety conditions or sign a commitment to comply with food safety regulations. The proportion of agricultural, forestry and fishery food processing and processing establishments certified with HACCP and ISO 22000 (or equivalent) increased by 10 % per year and 15 % per year, respectively. The rate of monitored agricultural, forestry and fishery food samples violating food safety regulations is below 3 % per year. Additionally, 100 % of agricultural, forestry and fishery quality and food safety management officers at all levels are trained and updated annually on professional expertise (7).

Status of cultivation of major crops

According to the data collected from the Department of Crop Production and Protection of Can Tho City, the status of cultivation of major crops in the study area can be described as follows:

Rice

The total area of rice cultivation for the year 2023 is 216215 hectares, yielding 1367086 tons of production, with a yield of 6323 tons/ha (8). In the first six months of 2023, the total sown area was 169848 hectares, a decrease of 6.10 % compared to the same period. The rate of using high-quality rice varieties and specialty aromatic varieties is over 90 %.

Currently, fresh rice OM18 is sold by many farmers for up to 6500 - 6700 VND/kg (≈ 0.26 US dollars), while rice varieties IR 50404, OM 380 and OM 5451 are priced from 6000 - 6500 VND/kg (≈ 0.24 to 0.26 US dollars). With current selling prices, if the rice yield reaches 800 kg/1300 m^2, farmers can earn between 1.5 and 4 million VND (59 to 157 US dollars/1300 m^2) (8).

Vegetables

The total planted area of vegetables, crops, beans and short-term industrial crops in 2023 has reached 15532 hectares, 0.6 % higher than planned, with an estimated output of 192333 tons, 25 % higher than planned. Localities in Can Tho City have formed concentrated vegetable-growing areas with an area of 229 hectares and an output of 28390 tons.

Farmers growing vegetables and fruit trees also link and cooperate in large-scale production, ensuring quality and safety and meeting domestic and export needs. Farmers have promoted the application of digital technologies (Using UAVs to spray pesticides and fertilize or using QR codes to buy and sell rice and agricultural materials), which have performed well in management, creating peace of mind and convenience for producers and consumers. It has motivated farmers to improve the quality of agricultural products, ensure the production process and product origin are clear, meet market demand and avoid the situation of "good harvest - bad price".

Longan

The total longan cultivation area is 2611.34 hectares, of which 1845.71 hectares of fruit growing area had an output of 22739.15 tons. The "Ido longan" variety, characterized by thin skin, small seeds, thick flesh and a sweet aroma, is primarily grown in the City and is consumed both domestically and exported. It is a group of fruits that can expand the market for consumption.

Durian

The city's durian growing area is 2965.28 hectares. Durian-growing areas are developing rapidly in many districts, aiming to ensure quality and safety according to VietGAP and GlobalGAP standards, while also paying attention to establishing growing area codes.

Star apple

According to the data collected, the area of star apple cultivation in Can Tho City exceeds 1482.33 hectares, with an estimated output of over 123.75 tons. The Can Tho star apple has many diverse varieties, the most significant being the "Lo Ren" star apple, which covers more than 950 hectares, along with other varieties.

Mango

The mango-growing area in Can Tho City is approximately 3373.96 hectares, yielding 16281.86 tons, primarily of the "Hoa Loc" mango and Taiwanese mango varieties.

Jackfruit

The entire City has 1962.43 hectares of jackfruit-growing area, with the current area allocated for the product being 1029.71 hectares (52.47 %), yielding 92.76 tons/ha. In 2022, the jackfruit growing area in Can Tho will increase by 48 % compared to 2021.

The potential and recommendations of circular models for major crops in the study area

As mentioned above, the main crops in Can Tho City are diverse. However, within the scope of this study, only three crop models with the largest land area are proposed, including rice (216215 hectares), vegetables (15534.86 hectares) and mango (3373.96 hectares).

Circular rice system

Fig. 1. presents the proposed directions for using rice based on the survey results of 36 experts.

The model "Paddy-straw–building materials" was proposed by only 3/36 experts, accounting for 8.3 % of the votes. This model is underestimated because biological

materials are still relatively new in Vietnam today; not many people are aware of this type of material and its advantages. However, the effectiveness of this model was observed, where 1 ton of rice obtained is equivalent to 1 ton of straw discharged in the field. The environment will suffer severe impacts without measures to use this by-product source. It is truly an effective and positive direction in Can Tho and Vietnam, given the situation where millions of tons of straw are being burned and wasted each year. Social benefits will also be obtained when using straw as a construction material, promoting straw collection after each season and creating jobs and income for farmers from rolling straws (9).

11/36 (30.6 %) interviews were proposed for the model "Paddy - straw - animal feed." The model "Paddy - rice - rice flour - food processing" received 13/36 votes, export (36.1 %). The model "Rice - rice husk - rice husk charcoal - organic fertilizer" accounted for 15/36 votes (41.7 %) and the model "Rice - rice husk, straw - organic fertilizer" (58.3 %). These models received lower preference due to their longer history of use in Vietnam, making them less novel but still economically viable. However, these models can help mitigate the increasing amount of by-products discharged into the environment, thereby bringing better economic value and widespread use.

The most proposed model is "Rice - straw - mushroom growing - organic fertilizer," with 32/36 votes (88.9 %). Farmers often burn straw after harvesting rice, generating CO_2 and CH_4 gas. It can easily lead to the risk of poisoning rice plants and causing greenhouse emissions. Therefore, experts highly appreciate this model's economic efficiency, its savings on raw material costs and its environmental friendliness.

Straw also brings profits to farmers. After deducting costs, each straw rolling crop lasting half a month can earn nearly 15000000 VND (≈ 590.4 USD). The wage for rolling a roll of straw is 8000 VND (≈ 0.31 USD) and the selling price of a roll of straw in the field is 30000 VND (≈ 1.18 USD)/1 roll (10). Taking advantage of straw resources to cultivate mushrooms helps reduce the cost of organic fertilizer, helping increase profits. Therefore, reusing materials in production has significantly saved production costs. It is a widely applied usage direction in practical production because it is suitable for various subjects with large, medium and small production scales (11).

From the results of interviews with experts on the proposal to use rice circularly, a circular production model for rice is summarized (Fig. 2). This activity will maximize the utilization of by-products during the rice harvesting process, help reduce field burning emissions after each crop and lower production costs. In addition, by-product resources are utilized to enhance the diversity of rice products and promote the production value chain, resulting in safer and higher-quality products. It will also create more jobs for local people, bringing great social value.

Circular vegetable system

The results obtained from the survey of 36 experts are presented in Fig. 3.

The "Seeds - oil pressing" model received the lowest number of votes (7 out of 36 votes, accounting for 19.4 %). Experts have rated this direction of use as the lowest due to its low popularity. However, when pressed for oil, plant seeds provide high nutritional value for human health. Many types of plant seeds can be pressed to produce valuable oils and other products. Organic perilla seed oil is one of the seed oils with the highest nutritional and economic value.

Perilla seeds have a high oil content of 35 to 45 %, containing a variety of unsaturated fatty acids, including oleic acid, linoleic acid and alpha-linolenic acid. Compared to other vegetable oils, perilla oil has the highest linolenic acid content, ranging from 54 to 64 % (12, 13). It is a good source of polyunsaturated fatty acids, offering benefits such as antitussive and anti-inflammatory effects (14).

The "Vegetables-processing" model is rated by experts at a relatively low level, accounting for 9 out of 36 votes (25 %). It is an easy-to-implement and widely popular model. Vegetable and tuber products retain their nutritional value and are preserved longer, without fear of spoilage or nutrient loss. However, the circulation level is not high due to the requirement to invest in advanced equipment and techniques suitable for businesses. In particular, drying can be an optimal solution for preserving vegetables for longer and making them more convenient for use.

The two models, "Vegetables - fresh food" and "Tubers –residue, Peels-animal feed," were proposed by experts at an average level of 15/36 (41.7 %) and 16/36 (44.4 %), respectively.

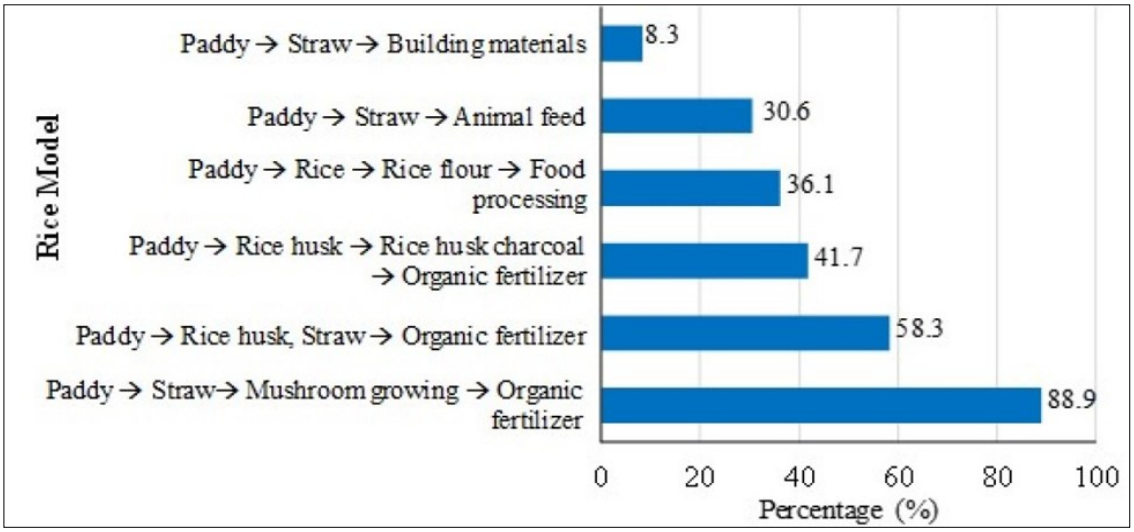

Fig. 1. The proposed circular rice models.

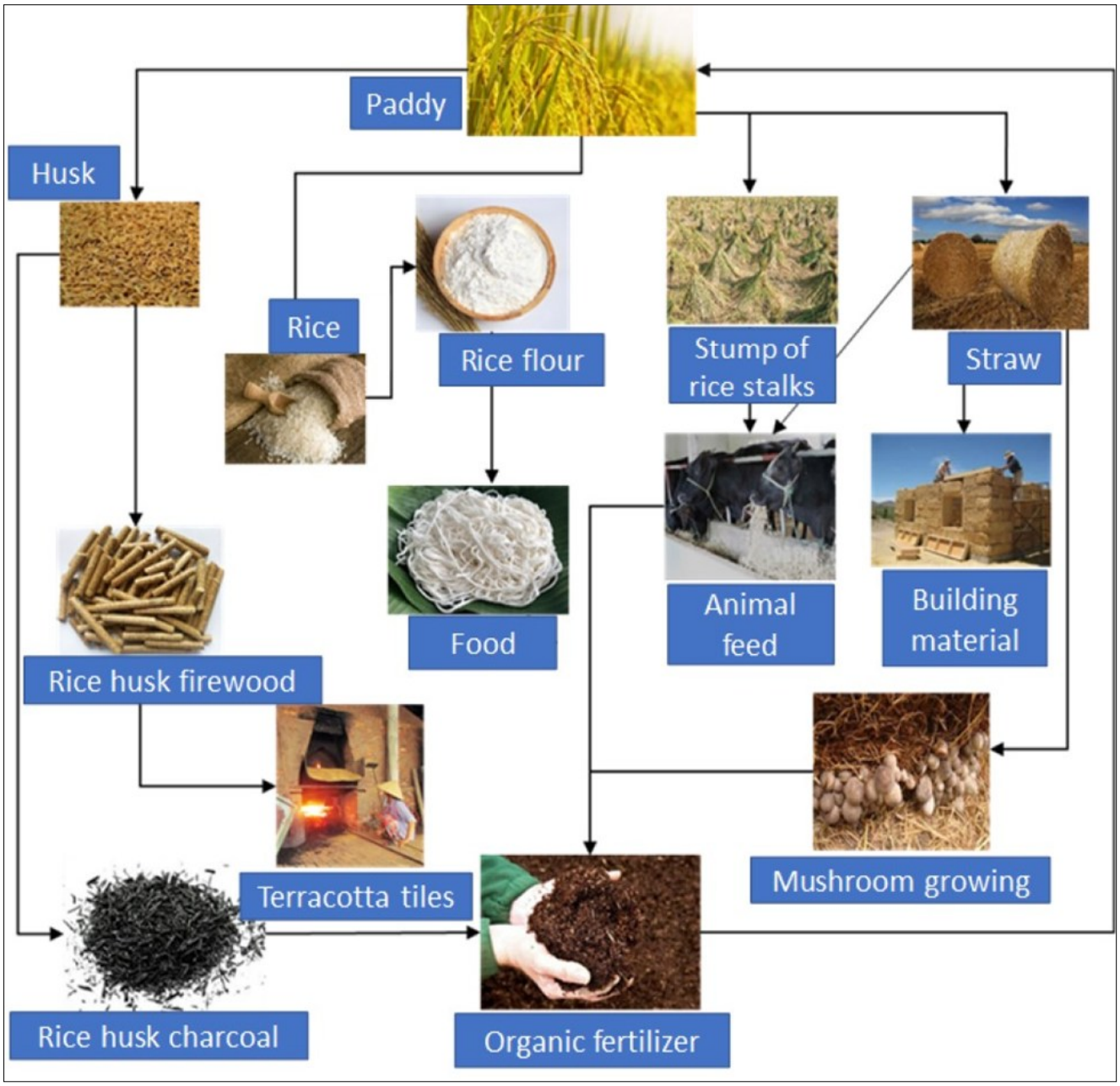

Fig. 2. Circular rice model.

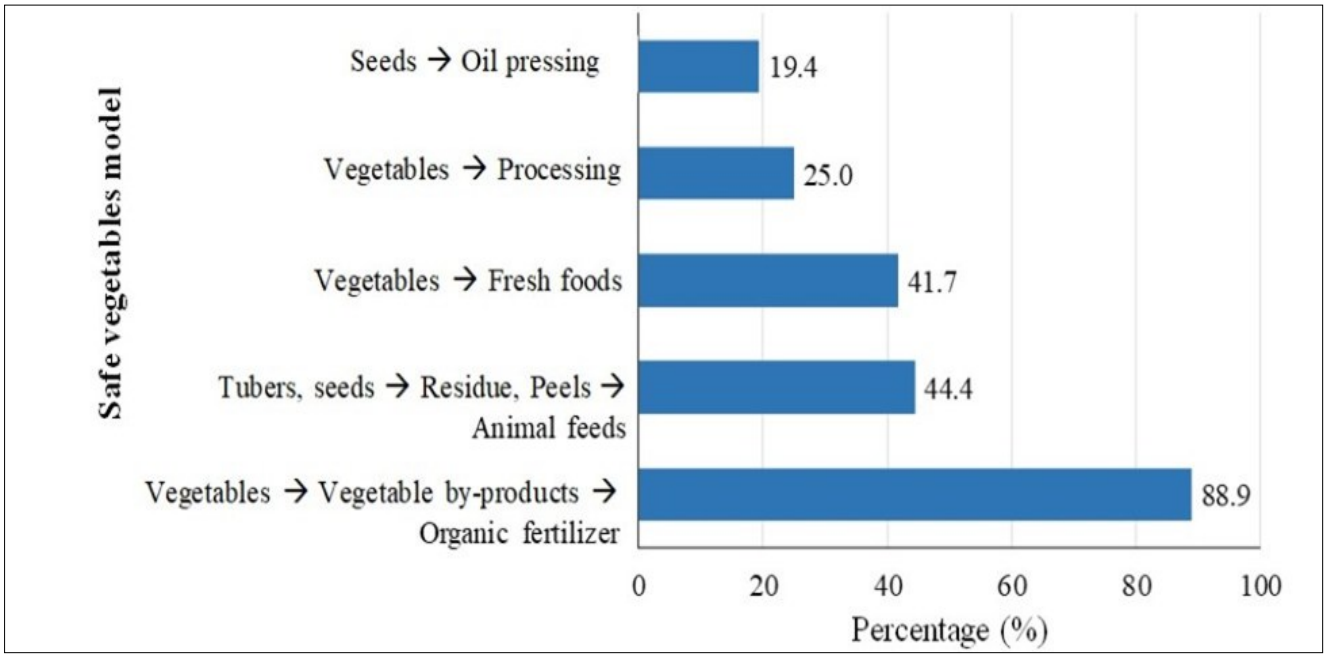

Fig. 3. The proposed circular vegetables.

The "Vegetables - fresh food" model is the most popular usage direction because fresh vegetables and tubers provide a significant amount of nutritional value and bioactive substances, including vitamins, fiber and minerals (15). Some herbs and spices possess medicinal properties due to their essential oils and plant-based compounds that act as antibiotics. Notably, the model "Tubers, seeds - residue, peel - animal feed" is prevalent in rural areas. After being processed, tubers and seeds will have residue and shells. This food source provides high nutritional value to livestock, including soybean residue, cassava shells and peanut shells.

The global plant-based food market is experiencing strong growth and is closely tied to sustainability. If the residue left after pressing the seeds, which is currently essentially unusable, could be reused, it would not only be rich in nutrients and high in fiber but could also reduce and slow down food surplus. Okara (soybean residue) is a by-product, specifically the insoluble portion of the soybean. It consists of high moisture (8.4–22.9 % DW) and other components, including crude protein (20.9–39.1 %), crude fiber (12.2–61.3 %), crude fat (4.9–21.5 %) and ash (3.4–5.3 %) (16). The fermentation process of soybean residue improves nutritional quality and reduces anti-nutrient content. Due to its palatability to animals, okra can be used to wholly or partially replace soybean meal or concentrate in animal diets. Additionally, soybean residue is expected to become a low-calorie, high-fiber plant-based food source, capable of replacing fetal bovine serum in meat culture.

The model "Vegetables - vegetable by-products - Organic fertilizer" received the most significant number of votes, 32/36 (accounting for 88.9 %). Experts recommend this direction of use because vegetables are a type of food. It is grown and consumed the most, but is challenging to preserve at outdoor temperatures. High annual temperature conditions, such as those in Vietnam, make preserving vegetables at outside temperatures difficult. Vegetables spoil quickly, often within one to two days. If a large amount of damaged vegetables is thrown away, it burdens the environment. These are the main ingredients used to create organic fertilizer (compost), a nutrient-rich substance that improves soil quality. The unique characteristics of properly composted and treated organic fertilizers are that they are odorless, non-polluting and environmentally friendly (17). The spoiled vegetables and by-products, such as roots, stems and leaves, are utilized as organic fertilizers to protect the environment and minimize waste. This activity may provide a clean food source for users. This cycle is the optimal solution for a cleaner, greener environment, helping to save costs and be safe for people.

Currently, each bag of organic fertilizer sold ranges in price from 50000 VND (≈ 1.97 USD) to 80000 VND (≈ 3.15 USD). It is suitable for households because it provides a source of income for people who use it, enabling them to utilize this by-product in a circular manner. A circular model for safe vegetables in Can Tho has been proposed (Fig. 4). This model is expected to bring significant environmental, economic and social benefits, helping Can Tho City develop green agriculture and high profits for households.

Circular model for mango trees

Fig. 5 presents the results of interviews with 36 experts who are officers at Plant Cultivation and Plant Protection Stations directly working in Can Tho Cty.

The model "Mango - mango seeds - mango seed oil" was rated lowest by experts with 3/36 votes (8.3 %) because it is not widely popular among the people and there is no domestic research on the use of mango seeds and oil. However, mango seeds may be utilized in the future due to their numerous beneficial properties. Mango seed kernels contain 53.34 to 76.81 % carbohydrates, 5.20 to 10.48 % protein, 9.84 to 18.0 % fat/oil and 0.26 to 10.60 % crude fiber. Mango kernels are also a notable source of phytochemicals that can improve human health and prevent the growth of pathogenic microorganisms (18). The nutritional and bioactive compounds of mango seeds, as a promising food and therapeutic agent, include the methods and technologies used to extract the phytochemicals present in the mango seed kernel. Mango kernel fat is edible fat with high nutritional and functional potential. However, its application in the food industry has not yet been fully explored or developed.

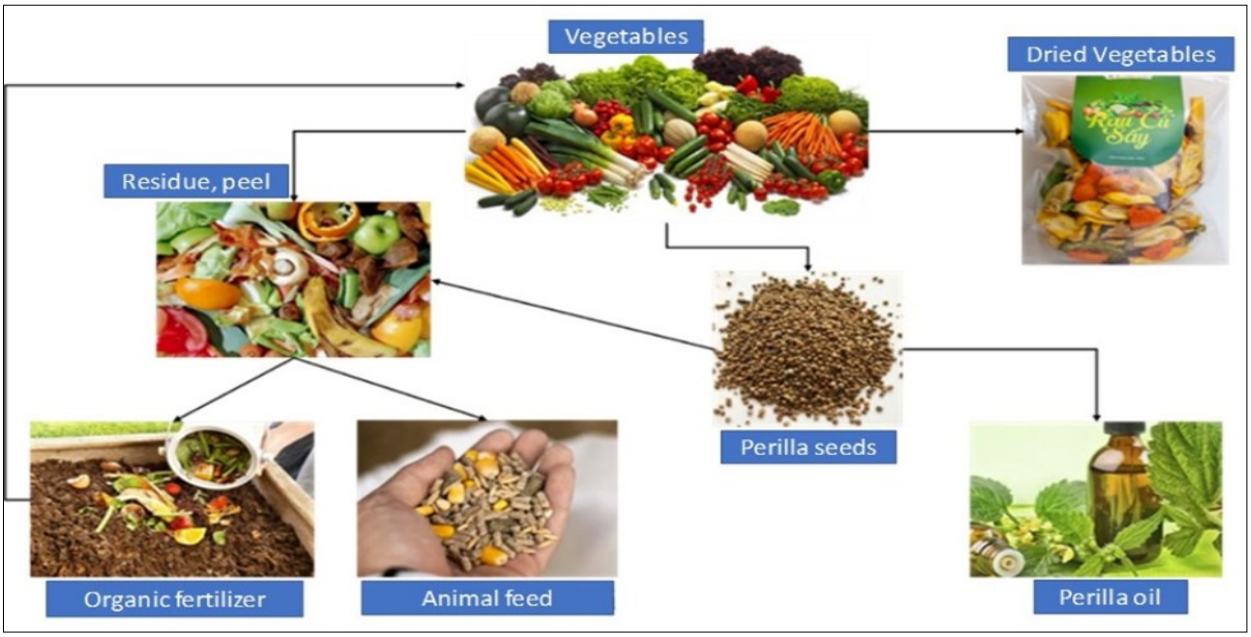

Fig. 4. The proposed circular vegetables.

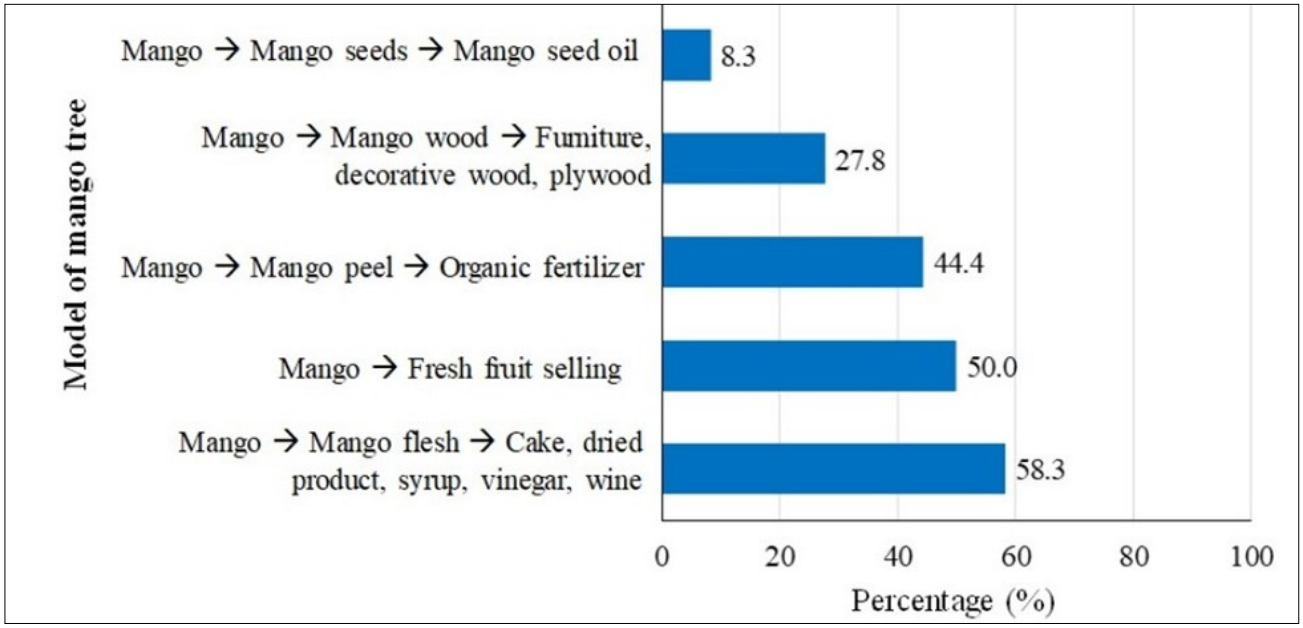

Fig. 5. The results suggest a circulation model for Mango trees.

The model "Mango - mango wood - furniture, toys, plywood" is also not highly rated, with only 10/36 votes (27.8 %). Although furniture products made from mango wood are beautiful and durable, the highest economic value comes from fresh fruit, so this use is only the last measure for mango trees that gardeners can consider.

Experts propose the model "Mango-mango peel-organic fertilizer" at a moderately supported level due to its circularity and ability to bring high economic and environmental value. The number of votes collected was 16/36 (44.4 %). It is considered a valuable resource for restoring organic matter to the soil. Mango-growing households and businesses can use this by-product source because composting is relatively easy to implement and highly effective.

The "Mango – fresh fruit selling" model, with 18/36 votes proposed (accounting for 50 %), is a direction of use that mainly brings one-time economic value and is not meaningful in the product production chain. However, this is the most used direction today. After harvesting the fruit, growers can sell it directly to consumers without applying additional processing techniques, which still add economic value. On the market, mango prices fluctuate enormously with each season, averaging 26000-48000 VND (≈ 1.02-1.89 USD) for 1 kg of Taiwanese mango varieties, 50000-60000 VND (≈ 1.97-2.36 USD) for 1 kg of "Hoa Loc" mango and 15000-30000 VND (≈ 0.59-1.18 USD) for 1 kg of Thai mango varieties.

Most experts recommend the model "Mango – mango flesh - cake, dried products, syrup, vinegar, wine," with 19/36 votes (58.3 %). Products made from mango pulp are widely available in the market and can be easily purchased in many places, so producing products from mango pulp will increase their use and consumption. The most popular items include dried mango, mango cake, mango syrup, mango vinegar and mango wine, which can serve a diverse range of audiences and purposes. In general, products made from mangoes have a much higher price than selling fresh fruit. With the same weight, 1 kg of dried mango on the market costs about 160000 - 200000 VND (≈ 0.59-1.18 USD). However, the complex problem is that high product quality requires more advanced technology and techniques and the source of raw materials must be stable to build a chain of links in product production, preservation and processing. Thus, this model is designed to help businesses develop into more outstanding ones.

Based on the above analysis, Fig. 6 presents a circular model of utilizing mango trees, outlining the direction for maximizing the value of mango by-products, enhancing the economic value of mango trees to support circular economic development and achieving green and sustainable growth.

SWOT analysis

A SWOT analysis helps to identify the model's strengths, weaknesses, opportunities and threats. It guides us to build on what we do well, address our lack, seize new opportunities and minimize risks. Apply a SWOT analysis to assess the model's position before deciding on any new strategy and propose solutions to implement the circular model. Favorable factors were identified based on the results obtained from interviewing 36 experts about the factors affecting the proposed models for some of the major crop groups in Can Tho City benefits, difficulties, opportunities and challenges presented in Table 1.

Developing a circular model is a new concept for many people and there is currently no policy in place to support it. The country has no criteria to identify, evaluate, summarize and accurately classify the circular model's development level. Therefore, there are limitations in terms of implementation; farmers and stakeholders lack awareness and access to implementation guidance and cannot apply it.

The results of analyzing the favorable factors, difficulties, opportunities and challenges when applying the proposed model to major crop groups in Can Tho City suggest solutions for implementing the circular model to capitalize on strengths, seize external opportunities, address weaknesses and mitigate threats (Table 2).

S-O strategy

S3–O4: Utilize available by-product materials from crops to diversify products, enabling them to reach the market through the circular model.

Table 1. Favorable factors, difficulties, opportunities and challenges for the proposed circular models

SWOT	Positive/beneficial	Negative/unbeneficial
	Strengths	**Weaknesses**
Internal factors	S1: Cooperatives are receiving attention for development S2: The development of science and technology S3: Availability of raw materials S4: Convenient transportation S5: Favorable geographical location for trade S6: Farmers accept the reasonable application of science and technology in production.	W1: Agricultural production is still fragmented, not yet centralized and linked W2: Local forces are still small W3: Lack of supporting equipment W4: People lack professional qualifications W5: Consumption links are not tight and are subject to many uncertainties from market prices.
	Opportunities	**Threats**
External factors	O1: Infrastructure is being paid attention to and invested in by the State. O2: Market demand for environmentally friendly products is increasing. O3: The process of international economic integration is going strong. O4: Circular agriculture is being paid attention to and encouraged O5: Pressure from environmental pollution, the large amount of waste.	T1: There is no market outlet for the products yet T2: Market prices fluctuate constantly T3: Competition for imported products T4: Need investment capital for many aspects T5: Requires professional equipment and appropriate techniques for each stage T6: Developing a circular model is a new issue for people and there is no policy to support it.

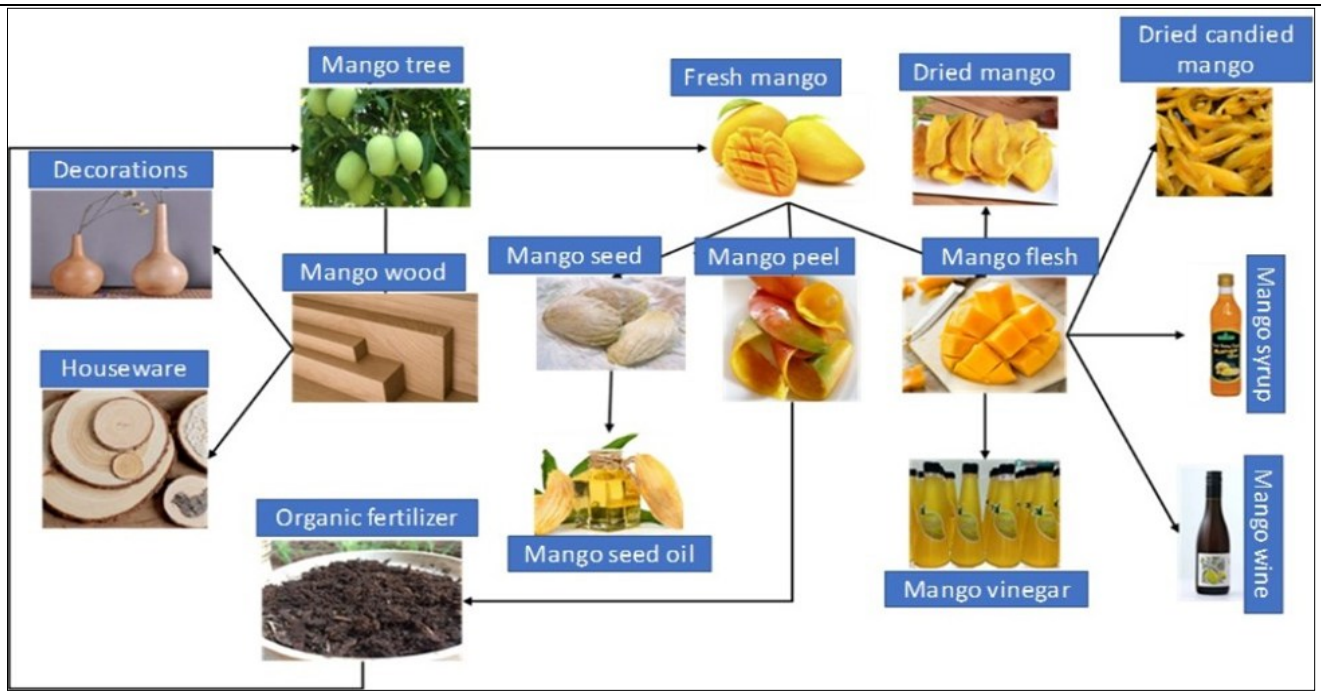

Fig. 6. Circular model for mango.

Table 2. Proposed strategic solutions for circular models

No.	Strategies	Recommended solution
1	Strategy S – O	S3-O4: Take advantage of available raw materials to diversify products. S1, S5-O1, O2: Create links between manufacturers, cooperatives and businesses to ensure the supply of input materials and output products. S1-O4: Promote cooperative development so people can easily access the circular model. S2-O5: Finding new markets and consumers for circular agricultural products. S6-O3: Farmers accept and apply science and technology well to help promote the development process of international economic integration.
2	Strategy W – O	W4-O1: Develop training programs and train professional human resources to meet the requirements of advanced machinery and equipment. W3-O4: Promote cooperation with local and national agencies to obtain funding to support circular model development. W3-O1: Take advantage of new investments built by the state and upgrade infrastructure for product transportation and distribution. W5-O5: Create close consumption links and stabilize prices so that more products from by-products are consumed, helping to reduce pressure on the environment.
3	Strategy S – T	S2-T5: Upgrading and adding production support equipment. S1-T4: Develop policies to support loans and provide equipment for people. S2-T2: Build a widespread marketing and promotion strategy. S2-T1: Seeking cooperation and association with international partners. S2-T3: Developing a standards and certification program for circular agricultural products.
4	Strategy W – T	W4, W2-T6: Develop training and education plans to improve people's expertise in circular agriculture. W5-T1: Seek solutions for cooperation and association with large agricultural units. W5-T2: Continuous market assessment and analysis. W3-T5: Build links with research organizations and universities to leverage the latest expertise and techniques.

S1, S5–O1, O2; S2–O5: Create consumption links between manufacturers, cooperatives and businesses to ensure the supply of input materials and output products. From there, finding new markets and consumers for circular agricultural products becomes more accessible.

S1–O4; S6–O3: Promote the development of cooperatives so that people can access the circular model, accompanied by farmers who effectively adopt and apply science and technology, thereby promoting the international economic integration process.

W–O strategy

W4, W3–O1: Take advantage of new investments from the state, build and upgrade infrastructure, develop training programs and train professional human resources to meet technical requirements and advanced equipment.

W3–O4: Seize the opportunity for circular agriculture to receive attention to promoting cooperation with local and national agencies, with funding to support the development of circular models.

W5–O5: Encourage the use of circular products to reduce pressure on the environment, thereby creating a closed consumption link and stabilizing prices.

S–T strategy

S2–T5: Apply advances in science and technology to upgrade and supplement equipment to support circular agricultural production.

S1–T4: Develop additional policies to support loans and provide equipment for people to make circular agriculture easier to implement.

S2–T2: Develop a marketing strategy and promote circular products to create trust and reach customers more efficiently.

S2–T1: Use technological developments to popularize, seek cooperation and connect with international partners to expand consumption markets. It will create conditions for circular products to become more popular and encourage people to adopt circular production practices.

S2–T3: Develop a standards and certification program for circular agricultural products to build customer trust. It must be done because circular products are relatively new and have not been widely tested to specific standards.

W – T strategy

W2–T6: Develop policies to support equipment and training, improve people's expertise in circular agriculture and attract workers from other places.

W1–T1: Find solutions to cooperate and link with large agricultural units to focus on the production and distribution of products to the market.

W5–T2: Continuously evaluate and analyze the market to stabilize circular product prices, creating conditions for products to reach a wider audience.

W3–T5: Build links with research organizations and universities to use the latest professional knowledge and techniques and equip appropriate machinery and equipment for each stage.

Conclusion

The main crop groups surveyed include rice, vegetables, longan, durian, star apple, mango and jackfruit. Based on the collected data, four groups of the most suitable economic, social and environmental solutions have been proposed for these major crop groups. Among them, the three crops with the largest planted area are rice, vegetables and mango, which were proposed for developing circular models. The SWOT analysis led to the identification of four key solution groups of circular model development: (i) economics - supply chain linkage, improving the value of agricultural products, expanding consumption markets; (ii) social – utilize and enhance the local labor force and attract more workers from elsewhere, improve infrastructure; (iii) environment – bringing environmentally friendly products closer to consumers, making the most of by-products, minimizing negative impacts on the environment; (iv) policy - develop training programs to improve professional qualifications and loan support policies to develop a circular model.

It is possible to expand the scope of research on the circularity of the proposed products. Additionally, more detailed research is needed on the technology and production process for each product within each circular model. This study is an essential foundation for developing sustainable green agriculture in Can Tho City.

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Authors' contributions

VQM carried out the studies, participated in the experimental design and drafted the manuscript. VQM and NTNH participated in the design of the study and performed the statistical analysis. PCD conceived of the study and participated in its design and coordination. TTNG carried out the experiments. NMT participated in the alignment and conceived of the study and participated in its design and coordination. All authors read and approved the final manuscript.

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Conflict of interest: Authors do not have any conflict of interest to declare.

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References

1. FAO. Moving forward on reducing food loss and waste. Food and Agriculture Organization of the United Nations; 2019.
2. Government of the Socialist Republic of Vietnam. Encourage the treatment of agricultural by-products for reuse for other purposes; 2021.

3. Vu T. Can Tho: Circular agriculture creates "double" economic and environmental benefits. Environmental Economics E-Magazine; 2022.
4. Hutchinson. A review of Essentials of statistical methods. Rumsby Scientific Publishing. Eur J Eng Educ. 1993;21.
5. Humphrey A. SWOT analysis for management consulting. SRI Alumni Newsletter. SRI International; 2005.
6. Trung K. Green agriculture affirms its superiority. Can Tho Online Newspaper; 2022.
7. Thao P. Plan to ensure food safety and improve the quality of agricultural, forestry and fishery products in the agricultural sector in 2023; 2023. https://www.cantho.gov.vn/wps/portal/home
8. Trung K. Diversify production and improve crop efficiency. Can Tho Online.
9. Bac Ninh Farmers' Association. Resources of crop by-products in circular agriculture; 2021.
10. Linh N. Running around the fields in the sun to collect waste to help farmers earn millions of dong daily; 2024.
11. Lan K. Farmers in Go Cong Tay district: Using straw after harvest, straw rolling is a reasonably stable source of income; 2023.
12. Asif M. Health effects of omega-3, 6, 9 fatty acids: Perilla frutescens is a good example of plant oils. Orient Pharm Exp Med. 2011;11 (1):51–9. https://doi.org/10.1007/s13596-011-0002-x
13. Nitta M, Lee JK, Ohnishi O. Asian Perilla crops and their weedy forms: their cultivation, utilization and genetic relationships. Econ Bot. 2003;57(2):245–53. https://doi.org/10.1663/0013-0001(2003)057[0245:APCATW]2.0.CO;2
14. Lee KY, Rahman MS, Kim AN, Son Y, Gu S, Lee MH, et al. Effect of freeze-thaw pretreatment on yield and quality of perilla seed oil. LWT. 2020;122:109026. https://doi.org/10.1016/j.lwt.2020.109026
15. Thuy NM, Tuyen NTM. Textbook on fruit and vegetable processing techniques. Can Tho University Publishing House; 2017.
16. Rahman MM, Mat K, Ishigaki G, Akashi R. A review of okara (soybean curd residue) utilization as animal feed: nutritive value and animal performance aspects. Anim Sci J. 2021;92(1):e13594. https://doi.org/10.1111/asj.13594
17. The Office of Sustainable Production and Consumption - Ministry of Industry and Trade. Sustainable consumption and production composting organic waste; 2021.
18. Choudhary P, Devi ThB, Tushir S, Kasana RC, Popatrao DS, K N. Mango seed kernel: a bountiful source of nutritional and bioactive compounds. Food Bioproc Technol. 2023;16(2):289–312. https://doi.org/10.1007/s11947-022-02889-y

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