Bioscience Evidence 2026, Vol.16, No.5, 384-400
http://bioscipublisher.com/index.php/be

Feature Review Open Access

Valorization of Peel and Processing By-Products from Changshan Huyou

Fangyuan Dong
People's Government of Tonggong Township, Changshan County, Changshan, 324216, Zhejiang, China
Corresponding email: 2676906696@qq.com

Bioscience Evidence, 2026, Vol.16, No.5 doi: 10.5376/be.2026.16.0029
Received: 28 Aug., 2026
Accepted: 21 Sep., 2026
Published: 28 Sep., 2026

Copyright © 2026 Dong, This is an open access article published under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Preferred citation for this article:
Dong F.Y., 2026, Valorization of peel and processing by-products from Changshan Huyou, Bioscience Evidence, 16(5): 384-400 (doi: 10.5376/be.2026.16.0029)

Abstract The processing industry of Changshanhuyou (*Citrus aurantium* 'Changshanhuyou') has developed rapidly. At the same time, the production of juice, preserved fruit, fruit tea, and other processed products generates increasing amounts of by-products, including peel, pomace, seeds, and segment membranes. Improving the comprehensive utilization of these by-products has become an important issue for increasing the quality and economic benefits of the Huyou industry. Based on actual agricultural production and processing practices, this study systematically analyzes the composition characteristics, product utilization pathways, and industrial development conditions of the main by-products from Changshanhuyou processing. Particular attention is given to the potential use of the peel in traditional foods, essential oils, pectin, dietary fiber, and functional components. The study also discusses the reprocessing of pomace, fiber-based utilization, seed utilization, and agricultural recycling. On this basis, and considering the actual capabilities of family farms, farmers' cooperatives, small and medium-sized processing enterprises, and specialized processing enterprises, a four-level cascading utilization model is proposed: "direct food utilization–food ingredient utilization–functional product development–agricultural reuse of residues." The development of Changshanhuyou by-products should follow the principles of classified collection, multi-level processing, and division of work among different production entities. Priority should be given to foods and food ingredients with mature technologies and an established market. High-value products can then be developed through cooperation among industry, universities, and research institutions. In this way, a whole-fruit utilization chain can be formed, covering fresh fruit processing, value-added use of by-products, and agricultural reuse of the remaining residues. This study provides a reference for value enhancement and circular development of the Changshanhuyou industry.

Keywords Changshanhuyou (*Citrus aurantium* 'Changshanhuyou'); Fruit peel; Processing by-products; High-value utilization; Case analysis; Bottlenecks and development

1 Introduction

Changshan Huyou (*Citrus aurantium* 'Changshanhuyou') is a representative local citrus resource of Changshan County, Zhejiang Province. It is characterized by strong adaptability, good storage and transportation tolerance, and suitability for both fresh consumption and processing, while also possessing potential value for food and medicinal product development. After decades of development, the Changshan Huyou industry has gradually evolved from fresh-fruit production alone into a distinctive regional industry integrating cultivation, processing, marketing, and brand development. Processed Huyou products now include juice, preserved fruit, jam, food flavorings, and several other product categories (He et al., 2023). From the perspective of local industrial development, approximately 106 000 mu of Changshan Huyou are currently cultivated, with a total annual production of approximately 136 000 tonnes. More than 200 specialized Huyou cooperatives and family farms and 64 agricultural leading enterprises at or above the county level are involved in the industry. In recent years, the utilization of Changshan Huyou has further expanded into diverse product categories covering beverages, foods, health-related products, personal-care products, medicinal products, aromatic products, ingredients, and tea products. By 2025, the output value of the entire Changshan Huyou industrial chain had exceeded RMB 7.4 billion, with 115 products across eight major categories. As the proportion of fruit used for processing and the diversity of processed products continue to increase, the focus of the Huyou industry has shifted beyond simply increasing the market value of individual fruits toward improving the comprehensive utilization and overall value of the whole fruit.

The expansion of Huyou processing inevitably results in the concentrated generation of peel, pomace, seeds, segment membranes, and fruits unsuitable for the fresh market. Citrus processing generally produces substantial quantities of solid by-products. These materials typically have high moisture contents and are generated seasonally; if they are not utilized promptly, considerable costs may arise from their storage, transportation, and disposal (Zema et al., 2018). From the perspective of resource composition, however, these by-products are far from valueless. Huyou peel and pomace contain dietary fiber, pectin, volatile compounds, flavonoids, and other potentially valuable constituents, providing a basis for their further development into food products and food ingredients (Gao et al., 2022). Huyou processing by-products therefore have the dual attributes of both “waste” and “processing raw materials.” When they are promptly separated, properly preserved, and directed toward appropriate product applications, they can become valuable raw materials for further processing. In contrast, prolonged accumulation and the absence of effective utilization pathways can turn these materials into wastes that impose additional disposal costs on processing enterprises.

Against this background, this study focuses on Changshan Huyou peel, pomace, and other major processing by-products and examines their product-oriented and resource-efficient utilization pathways from the practical perspectives of agricultural production and processing operations. The major processing methods of Changshan Huyou and the basic characteristics of by-products such as peel, pomace, and seeds are first reviewed. On this basis, product development from Huyou peel, comprehensive utilization of pomace, and appropriate utilization pathways for other processing by-products are discussed, followed by the development of a cascaded valorization model. Furthermore, considering differences among family farms, farmers' cooperatives, small- and medium-sized processing enterprises, and specialized processing enterprises in terms of equipment, capital, and technical capacity, this study analyzes practical constraints related to by-product collection and preservation, product development, standardization, and industrial-chain coordination. The aim is to provide practically applicable references for whole-fruit utilization, value-added processing, and the sustainable development of the regional Changshan Huyou industry.

2 Overview of Changshan Huyou Processing and By-products

2.1 Processing methods

At present, the Changshan Huyou industry combines fresh fruit sales with processing. In addition to fresh fruit, Huyou is processed into juice, preserved fruit, jam, food flavorings, and other products, showing that Changshan Huyou already has a good processing base. Huyou fruit has good storage and transportation tolerance and strong adaptability. In actual production, the fruit can be graded according to size, appearance quality, and maturity. Fruits with better market quality are mainly sold fresh, while other fruits that meet processing requirements are used for juice, preserved fruit, jam, and other food products.

Among the different processing methods, juice production is an important use of Huyou and is also a major process that generates by-products such as peel, pomace, and seeds. Wu et al. (2021) studied the fermentation and storage of Huyou juice, showing that Huyou juice can also be used to develop fermented beverages. Li et al. (2020) pointed out that the fresh fruit market for Huyou is limited, and insufficient deep processing can lead to fruit spoilage and waste. Therefore, the development of juice, dried products, and other processed products can not only increase the variety of Huyou products but also help use more fruit during the concentrated harvest and marketing period.

2.2 Characteristics of Huyou peel

Huyou peel is one of the most important by-products generated during processing. Gao et al. (2022) systematically reviewed the chemical composition of Changshan Huyou and reported that 102 chemical components have been identified from its pulp and peel, including volatile oils, terpenoids, phenolic compounds, limonoids, and sugars. Huyou peel is therefore not simply processing waste but a plant material with further utilization value. It can provide raw materials for the development of essential oils, pectin, dietary fiber, and functional components.

The different components of Huyou peel provide several possible utilization pathways. Wang et al. (2024) analyzed essential oils from Huyou peel at different maturity stages and identified about 70 volatile compounds, indicating that the peel is a useful source of aromatic compounds. He et al. (2023) found that some flavonoids and antioxidant activities of Huyou peel increased after lactic acid bacteria fermentation. In addition, the solid residues remaining after pectin extraction from Huyou processing waste can be further processed into dietary fiber. Therefore, Huyou peel has the characteristic of "one raw material with multiple uses" and is a major target for further product development from Huyou by-products.

2.3 Pomace and other residues

In addition to peel, the by-products generated from Huyou processing include pomace, segment membranes, seeds, and some fruits that are unsuitable for the fresh market (Figure 1). Citrus fruits consist of different tissues, including the flavedo, albedo, pulp, and seeds. Therefore, different types of residues are naturally produced during juice extraction, segment processing, and other processing operations. These by-products differ in composition and utilization value. If they are all mixed together, further resource utilization becomes more difficult.

Pomace is one of the main solid by-products produced after juice extraction. It still contains dietary fiber and some plant bioactive components and can be further used in food production or fermentation. In a study on Huyou segment processing, Gu et al. (2024) found that the inedible segment membrane can affect the quality of fresh and processed products. Pectinase treatment can effectively remove the membrane while maintaining fruit color, sugars, and major flavonoids, indicating that the segment membrane itself is a processing residue with a specific composition. Although seeds are produced in relatively small amounts, studies on citrus seeds have shown that they contain oils, phytosterols, tocopherols, limonoids, dietary fiber, and other components, suggesting potential for further utilization (Zayed et al., 2021).

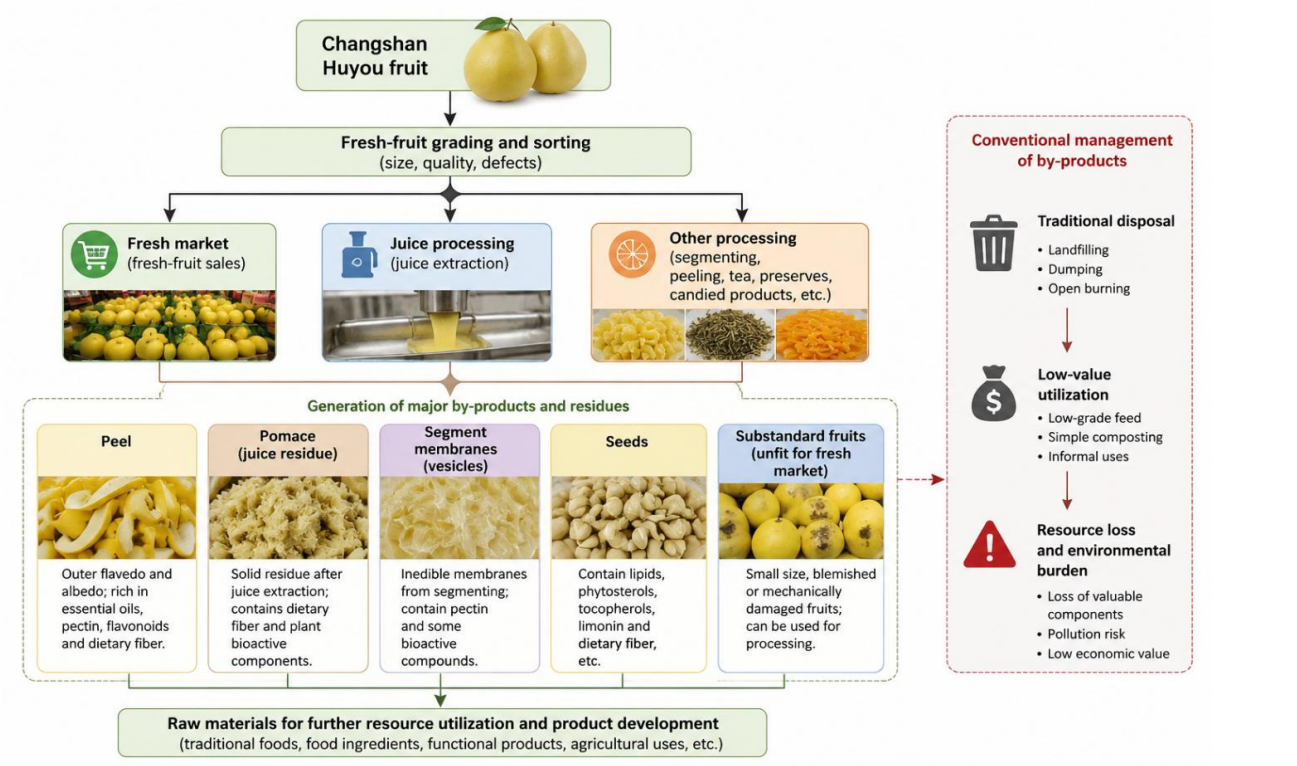


Figure 1 Major processing pathways of Changshan Huyou and generation of processing by-products

3 Product Development Pathways for Changshan Huyou Peel

3.1 Traditional food development

Traditional foods and local specialty foods remain the most practical products for the utilization of Changshan Huyou peel. More than ten types of Huyou products, including juice, preserved fruit, jam, and food flavorings,

have already been developed in Changshan, showing that the local Huyou industry has an established processing base. Lu et al. (2006) used HPLC to determine flavonoids in different citrus fruits and traditional food and medicinal materials in China. They found that the contents of naringin and neohesperidin in Huyou peel reached 3.25% and 2.76%, respectively, which were relatively high among the materials compared. Citrus peel, young fruit, and flowers have long been used in China for flavoring and tea products. For local processing enterprises in Changshan, Huyou peel can be made into Huyou tea, candied Huyou peel, preserved fruit, and jam. These products are consistent with traditional consumption habits and can also retain the natural bitter aroma and citrus flavor of Huyou.

For specific product development, mature processing methods used for other citrus peels can be adopted. For example, citrus peel can be processed by debittering, candying, drying, or mixing with fruit pulp to produce jam, preserved fruit, and snack foods. In this way, processing by-products produced in large amounts during the processing season can be turned into products for direct sale. For Changshan Huyou, this pathway does not require complicated extraction of bioactive compounds. Instead, practical problems such as peel bitterness, texture, sugar-acid ratio, and product stability should be addressed first. Based on these processes, a product series including “Huyou tea-candied Huyou peel-preserved Huyou fruit-Huyou jam” can be developed, linking peel utilization with local specialty foods and the souvenir market.

3.2 Essential oils and aromatic products

A large number of oil glands are distributed in the outer layer of Huyou peel, making it an important raw material for essential oils and natural aromatic products. Wang et al. (2024) studied peel essential oils from Changshan Huyou at different growth and post-ripening stages. About 70 volatile compounds were identified by GC-MS, and the composition of the essential oils changed clearly with fruit maturity. In particular, essential oil obtained from fruit stored for 60 d after harvest showed good antioxidant activity and inhibitory effects against Escherichia coli, Staphylococcus aureus, Salmonella, and Listeria. These results suggest that Huyou peel essential oil can be used not only as a food flavoring and seasoning ingredient but also for the further development of natural aromatic products and food preservation ingredients.

In terms of processing methods, complicated equipment is not always necessary. Zhang et al. (2025a) used lemon, navel orange, and pomelo peels as raw materials and applied cellulase-inorganic salt pretreatment combined with microwave steam distillation. The results showed that pretreatment improved the release efficiency of essential oils from peel oil glands. Essential oils from all three citrus materials also showed antioxidant and antibacterial activities, providing a useful technical reference for processing Huyou peel essential oil. For enterprises that do not need to produce purified essential oils, milder methods can also be used to develop natural flavor bases. Huang et al. (2026) treated Huyou peel residues left after juice extraction with a compound enzyme treatment. After treatment, citrus, floral, and sweet aromas became more noticeable, while bitterness and undesirable odors decreased. Several aldehydes, esters, and alcohols related to aroma improvement were also identified (Figure 2). Therefore, Huyou peel can also be developed into beverage flavoring liquids, flavor bases for tea beverages, and blended flavor ingredients, rather than being used only for refined essential oil production.

3.3 Pectin and dietary fiber

Pectin and dietary fiber are suitable food ingredients for the large-scale utilization of Huyou peel. Singhal and Hulle (2022) systematically reviewed the structure, extraction methods, and food applications of citrus pectin. They pointed out that citrus processing by-products are important commercial sources of pectin. Citrus pectin has gelling, thickening, and stabilizing properties and can be used in jams, jellies, beverages, and other foods. Akhter et al. (2024) compared the extraction of pectin from orange and lime peels using hydrochloric acid, sulfuric acid, nitric acid, and citric acid. Both types of peel produced high-methoxyl pectin. When citric acid was used to extract lime peel, the pectin yield reached 32.53%, and the obtained pectin showed good gelling properties. These findings indicate that Huyou peel can be used as a raw material for pectin production in addition to traditional food processing. The produced pectin can be reused in Huyou jam and beverages or supplied to other enterprises as a food ingredient.

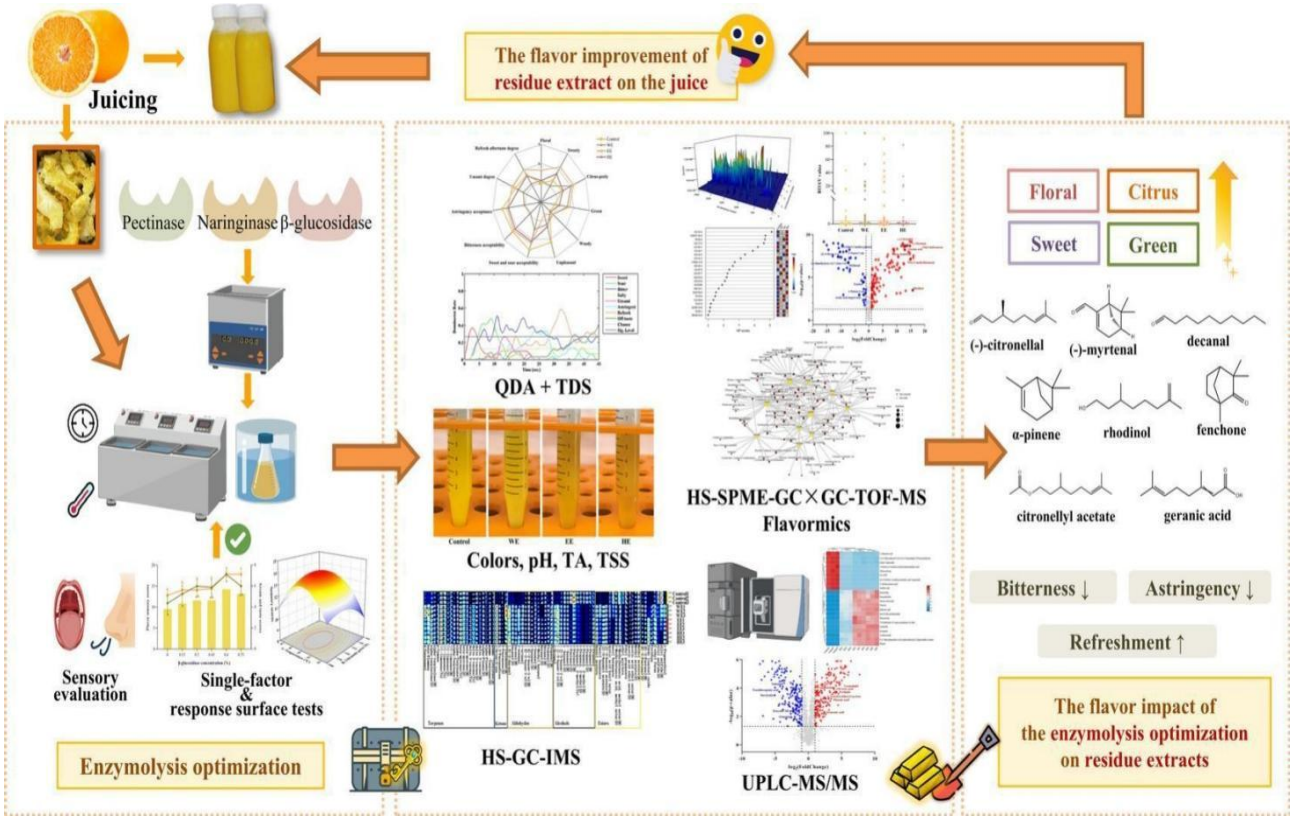


Figure 2 Schematic overview of flavor improvement of Changshan Huyou juice residue extracts by enzymatic hydrolysis and their application in juice (Adapted from Huang et al., 2026)

More importantly, the Huyou peel residue remaining after pectin extraction can still be further utilized. Debittered orange fiber produced from orange juice processing by-products can replace part of the fat in baked foods such as brioche, reducing fat content while increasing dietary fiber (Caggia et al., 2020). Therefore, a practical processing method for Huyou peel is to “extract pectin first and then produce dietary fiber.” In this way, one type of peel raw material can produce two types of food ingredients, improving the overall utilization rate of the raw material.

3.4 Product development of functional components

In addition to essential oils, pectin, and dietary fiber, Huyou peel contains various functional components that can be further developed. Gao et al. (2022) systematically summarized studies on the chemical composition of Changshan Huyou and reported that 102 chemical components have been identified from its pulp and peel, including volatile oils, terpenoids, phenolic compounds, limonoids, and sugars. Among them, flavonoids are one of the most widely studied groups. Therefore, juice is not the only valuable part of Huyou, as the peel itself also contains many potentially useful functional components. For agricultural enterprises, more practical development directions include Huyou flavonoid powder, mixed plant extracts, and tea beverage ingredients. There is no need to focus mainly on the complicated separation of high-purity individual compounds.

Zhou et al. (2024) provided more direct evidence for this product development pathway. The researchers used Changshan Huyou residues generated after juice processing by an enterprise in Quzhou, Zhejiang Province. Using water extraction at 40 ℃ for 30 min with a solid-to-liquid ratio of 1:7, they obtained an extract with good antioxidant activity. UPLC-MS/MS identified 29 secondary metabolites, including 12 flavonoids, 7 phenolic acids, 6 terpenoids, and small amounts of alkaloids, coumarins, and tannins. The extract also showed clear in vitro inhibitory effects on α-glucosidase and pancreatic lipase. These findings show that Huyou processing residues can be used as a source of mixed functional components (Figure 3). In actual industrial development, it is more practical to produce standardized Huyou extracts, functional beverage bases, or mixed food ingredients and then supply them to qualified enterprises for further product development. This can gradually form a multi-level product system covering “traditional foods-aromatic products-pectin and fiber ingredients–functional extracts.”

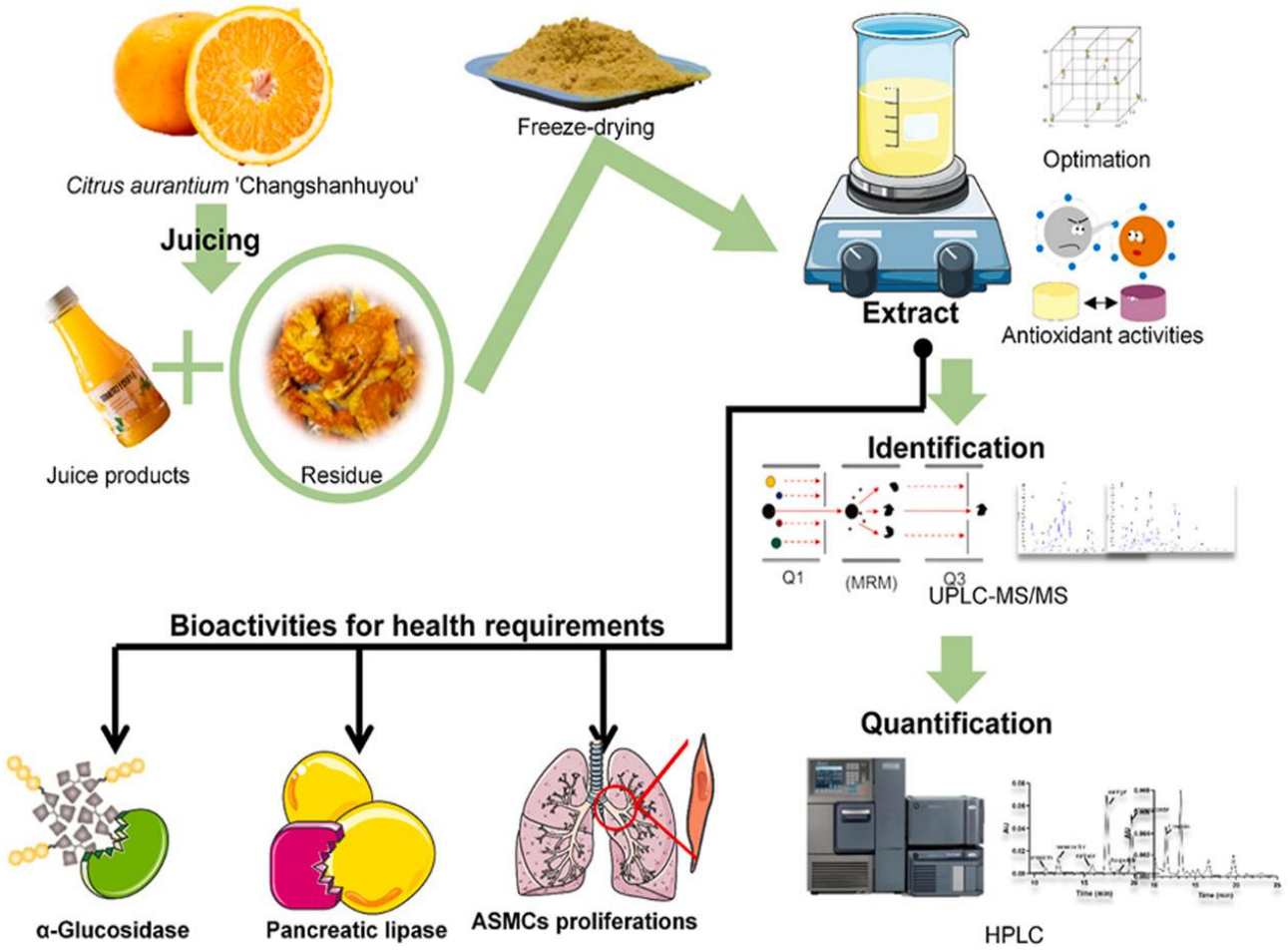


Figure 3 Valorization of Changshan Huyou juice-processing residues through recovery and bioactivity evaluation of functional components (Adapted from Zhou et al., 2024)

4 Comprehensive Utilization and Graded Pathways of Changshan Huyou Pomace

4.1 Reprocessing of huyou pomace

The pomace produced after Changshan Huyou juice extraction mainly includes pulp residues, peel fragments, segment membranes, and a small amount of seeds. It still contains useful components such as dietary fiber, pectin, sugars, and polyphenols, and therefore should not simply be treated as waste. Maqbool et al. (2023) reviewed the composition and utilization value of citrus processing waste and pointed out that citrus peel, pomace, and seeds still contain polyphenols, flavonoids, dietary fiber, pectin, and other substances that can be used to develop foods and functional ingredients. For Huyou processing enterprises, fresh pomace with good quality and a stable source can first be reused in food processing to produce fruit cakes, fruit puree, mixed jams, or beverage bases. This can reduce the accumulation of pomace during the main processing season and also create additional value after fresh fruit processing.

Huyou pomace can also be dried, ground, or extracted for use in other foods. Raczkowska and Serek (2024) reviewed the application of fruit pomace in food products and found that pomace has been used in bread, cakes, snacks, and extruded foods, mainly to increase dietary fiber and plant bioactive components. Kaur et al. (2025) studied the extraction of bioactive components from citrus pomace and found that ultrasound-assisted extraction could produce extracts containing phenolic compounds and flavonoids, with antioxidant and some antibacterial activities. Therefore, Huyou pomace can follow two utilization pathways. High-quality pomace can be directly used in foods such as fruit cakes and jams, while pomace requiring further processing can first be used to extract useful components, followed by further utilization of the remaining solids. In this way, the same batch of pomace can be used more than once.

4.2 Processing pomace into fiber products

For Huyou pomace to become a food ingredient that can be stored and sold for a longer period, the first problems to solve are its high moisture content and rapid spoilage. Redha et al. (2026) systematically compared different drying technologies for fruit pomace and pointed out that drying is an important step for stabilizing pomace, extending its storage life, and allowing further processing. Drying time, oxygen exposure, and temperature can all affect the retention of polyphenols and other bioactive components. For Changshan Huyou processing enterprises, pomace should therefore be collected and stabilized as soon as possible after production and then ground and stored, rather than being left in piles for a long time before treatment. In actual production, hot-air drying, vacuum drying, or other suitable methods can be selected according to the size and capacity of the enterprise, without necessarily using complicated equipment.

After stabilization, Huyou pomace can be further processed into crude fiber powder, refined dietary fiber powder, or mixed food powder. Selvaprasad et al. (2025) reviewed recent studies on the food utilization of citrus by-products and pointed out that dietary fiber is one of the products with good development potential from citrus peel and pomace. Suitable physical and enzymatic treatments can improve its performance in food processing. Therefore, Huyou processing enterprises can begin with the relatively simple “drying-grinding-sieving” process and use pomace powder in bread, cakes, cereal bars, and powdered beverages. Enterprises with better processing capacity can further develop refined fiber or soluble dietary fiber products. This approach fits the practical development of enterprises from simple processing to more advanced processing and can also expand the application range of Huyou pomace.

4.3 Seeds and other by-products

Although the amount of Huyou seeds is much smaller than that of peel and pomace, separate collection is still useful when fruits are processed on a large scale. Suri et al. (2021) systematically analyzed the utilization pathways of citrus processing waste and pointed out that citrus seeds contain oils and various useful components that can be developed into oil and other products. During Huyou juice and pulp processing, seeds can be separated from wet pomace, washed, dried, and stored together. For family farms and small enterprises, it is not necessary to build their own seed oil extraction lines. Instead, seeds can be collected until a sufficient amount is available and then sold or sent to specialized enterprises for processing, which can reduce equipment investment.

In addition to seeds, Huyou processing also produces small amounts of by-products such as segment membranes, segment walls, and fibrous pulp residues. Núñez-Pérez et al. (2026) studied the cascading utilization of lemon processing residues and pointed out that different residual tissues contain different amounts of pectin, fiber, and plant bioactive components. Therefore, separate collection makes it easier to select suitable utilization methods. This approach is also useful for Changshan Huyou. Segment membranes and pulp residues with a high fiber content can be included in pomace fiber processing, while seeds can be collected separately. This does not require many additional processing steps but can prevent all by-products from being mixed together and finally used only for low-value purposes.

4.4 Agricultural recycling

For Huyou pomace that is no longer suitable for food processing, feed use can be a practical regional utilization pathway. Corea-Guillen et al. (2025) conducted a meta-analysis to systematically evaluate the effects of citrus pomace in dairy cow diets on production performance and dry matter digestibility. The study indicated that citrus pomace can be used as a low-cost nutritional ingredient in ruminant diets, although its actual effects are influenced by the inclusion level, diet composition, and other factors. Fresh, ensiled, and dried citrus pomace can all be used as feed materials for ruminants. When Huyou pomace is used as feed, it should not simply be fed directly to animals. Suitable treatment and ration formulation should be carried out according to its moisture content, nutritional composition, and animal species. Establishing stable raw material supply relationships with local livestock enterprises should also be considered.

Residues of lower quality that are unsuitable for food or feed use can be stabilized and then used for soil improvement in orchards. Consoli et al. (2023) conducted a three-year field experiment in an orange orchard.

Citrus processing waste was applied at different rates to a 20-year-old sweet orange orchard, and its effects on soil physicochemical properties, microorganisms, tree nutrition, and fruit production were systematically evaluated. The results showed that citrus processing waste has potential as a source of organic fertilizer and a soil amendment. This model can also provide a reference for Changshan Huyou. Low-grade residues remaining after food and ingredient processing can be properly composted and safely treated before being returned to Huyou orchards or used in nearby agricultural production. In this way, a regional circular chain of "Huyou cultivation-fresh fruit processing-pomace utilization-return of remaining residues to farmland" can be established.

5 Cascading Resource Utilization Model for Changshan Huyou By-products

5.1 Levels 1 and 2: food and food ingredient utilization

The first level is the direct processing of Huyou by-products into food products. Huyou peel and some pomace can be used to produce preserved fruit, jam, fruit cakes, Huyou tea, and other products. These products use relatively simple processing technologies, require less investment in equipment, and can also reflect the local characteristics of Changshan Huyou. Citrus peel can retain some nutritional and functional components after being processed into jam and peel tea, while also showing good sensory acceptance (Jadhav et al., 2025; Negrea et al., 2025).

The second level is the further processing of Huyou peel and pomace into food ingredients such as pectin, dietary fiber, and peel powder. Compared with direct food production, this level requires better conditions for drying, grinding, extraction, and quality control. However, these products have wider applications and higher added value. Citrus peel and pomace are important sources of pectin and dietary fiber and can be used in baked foods, beverages, and mixed food products. Therefore, this pathway is more suitable for processing enterprises with suitable equipment and processing capacity (Huang et al., 2021; Chen et al., 2023; Kumar et al., 2023).

5.2 Level 3: development of specialty functional products

The third level mainly uses high-quality Huyou peel to further develop high-value components such as flavonoids, polymethoxyflavones (PMFs), and essential oils. Compared with the first two levels, this level has higher technical requirements, but the resulting products also have higher value. These components can be used in functional foods, nutritional ingredients, and related health products. Citrus peel contains various flavonoids and volatile compounds with good development potential. Among them, PMFs, naringin, hesperidin, and other components have received considerable attention (Peng et al., 2024; Chakraborty et al., 2025).

This level is more suitable for cooperation between processing enterprises, universities, and research institutions. Enterprises can provide raw materials and develop markets, while universities and research institutions can focus on extraction processes, quality evaluation, and product standards. This approach can reduce the cost of independent research and development for enterprises and can also improve product stability and market competitiveness (Munir et al., 2024; Sanli et al., 2025).

5.3 Level 4: agricultural reuse of remaining residues

The fourth level mainly deals with peel, pomace, and other organic residues remaining after the first three levels of utilization. Although these materials are no longer suitable for food processing, they can still be used for animal feed, composting, and organic fertilizer production. For a major Huyou-producing area such as Changshan, centralized treatment of processing residues followed by their use in orchards or nearby agricultural production can reduce the pressure of waste disposal and also lower some agricultural input costs (Suri et al., 2022).

This level is not simply "waste disposal," but the final part of the whole cascading utilization system. By returning the remaining residues to agricultural production, a circular process of "Huyou cultivation-fruit processing-by-product utilization-return of organic fertilizer to farmland" can be formed. This model does not require highly complicated technologies and is more suitable for the actual conditions of local agricultural enterprises and cooperatives. It is therefore an important supplementary pathway for achieving whole-fruit utilization and circular agriculture in the Changshan Huyou industry (Stavrakakis et al., 2025).

Overall, Changshan Huyou is suitable for a four-level utilization model of "food first-food ingredient upgrading-functional value addition-agricultural reuse" (Figure 4). Different business entities can participate in different levels according to their own conditions. Family farms and cooperatives can mainly focus on food processing, medium-sized enterprises can develop food ingredients, and large enterprises can work with research institutions to develop high-value products. The remaining residues can finally be returned to agricultural production. In this way, the graded utilization and overall value enhancement of Changshan Huyou by-products can be achieved (Hu et al., 2025).

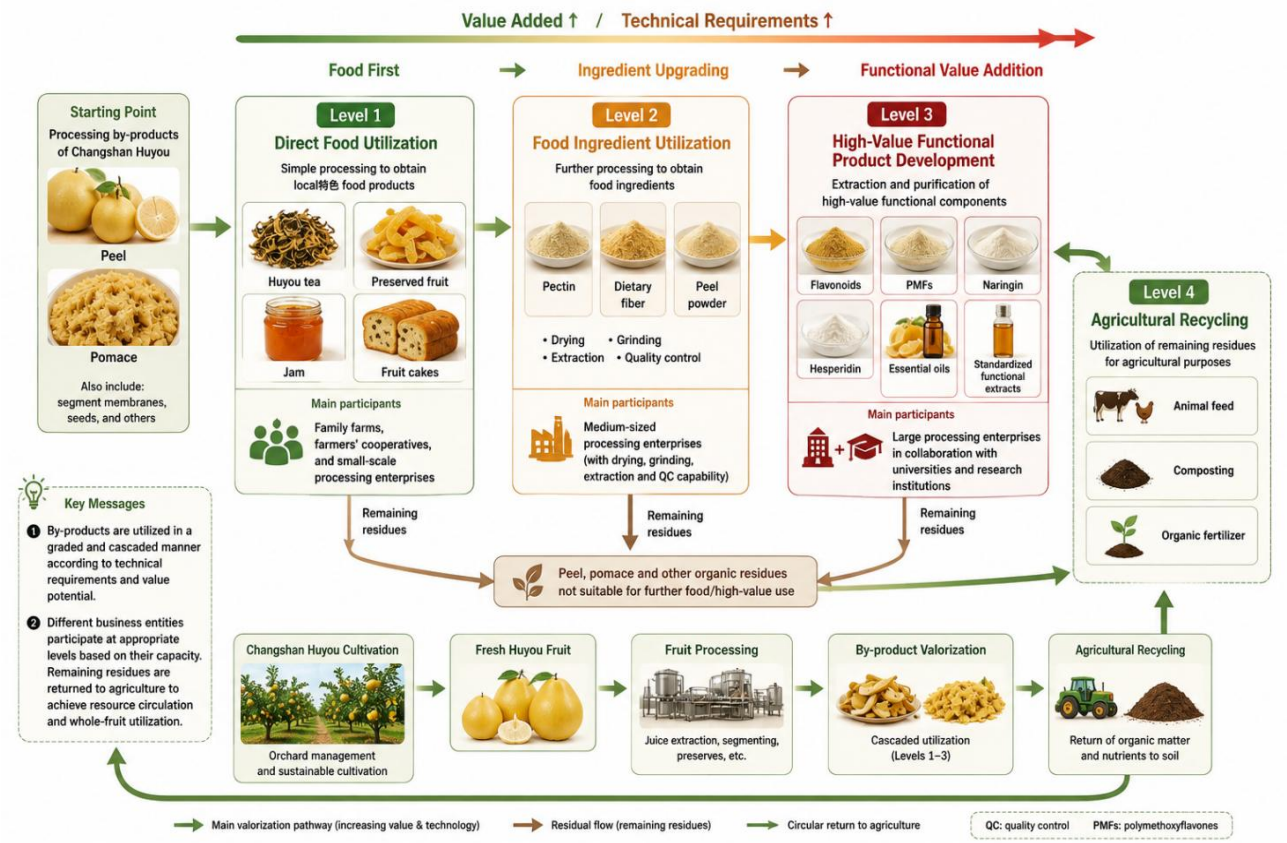


Figure 4 Cascaded valorization model for Changshan Huyou processing by-products

6 Case Studies on the Utilization of Changshan Huyou By-products

6.1 Cases of traditional processed products

Changshan Huyou processing has gradually expanded from mainly fresh fruit sales to a wider range of products, including juice, preserved fruit, fruit tea, and fruit paste. In 2024, Zhejiang Shuangyouyou Food Co., Ltd. launched a major construction project for the "deep processing of 28 000 tons of Huyou preserved fruit, substitute tea, and other foods annually". Preserved fruit products can directly use Huyou pulp and part of the peel, while substitute tea provides another product form for the combined utilization of peel, pulp, and other fruit parts.

Fruit juice is currently one of the more commercialized processing products in the Changshan Huyou industry, and its production directly affects the amount of peel and pomace generated. Sales revenue of Songyou Juice increased from RMB 35 million in 2021 to RMB 600 million in 2023. Its sales volume reached 11.3 million cases in 2023, of which 8.6 million cases were sold in Zhejiang. In early 2024, a filling production line with an annual output value of RMB 4.5 billion was officially put into operation. The company also signed cooperation agreements with seven distributors, 13 advertising agencies, and nine equipment suppliers. Zhejiang Aijia Fruit and Vegetable Development Co., Ltd. had also established a Huyou juice production line. In 2020, the company quickly adjusted and put into operation a production line with an annual capacity of 12 000 tons of Huyou juice, using some Huyou fruits with relatively low value in the fresh market for processing.

6.2 Case of comprehensive utilization of huyou peel

Compared with mature products such as juice and preserved fruit, the high-value utilization of Huyou peel and pomace is currently more closely linked to the process of "research verification-technology development-industrial application." Zhejiang Aijia Fruit and Vegetable Development Co., Ltd. and Zhejiang University have carried out related research on Huyou peel and pomace. He et al. (2023) reported that the frozen Huyou pomace used in their experiment came from whole-fruit processing and was provided by Zhejiang Aijia Fruit and Vegetable Development Co., Ltd. Fresh Huyou fruits were also provided by the same company. Lactiplantibacillus plantarum and Lactobacillus acidophilus were used separately for lactic acid bacteria fermentation of Huyou peel and pomace. After fermentation, viable lactic acid bacteria counts reached more than 8.0 log CFU/g. At the same time, the contents of flavonoids such as rhoifolin, quercitrin, and quercetin increased by more than 100%. The composition of some volatile compounds and aroma complexity also improved, while the scavenging capacities for hydroxyl radicals, superoxide anion radicals, DPPH radicals, and ABTS radicals all increased. These results show that Huyou peel and pomace generated from industrial juice processing can be further studied as materials for fermented foods or food ingredients, rather than being treated only as low-value residues.

Huyou peel and pomace generated during industrial processing usually contain a mixture of peel, segment membranes, and some pulp tissues, and their moisture content and composition can vary among processing batches. Zhang et al. (2025b) did not directly prepare ordinary dietary fiber from fresh Huyou peel. Instead, they used Huyou precipitated residues remaining after pectin extraction and produced Huyou citrus fiber through a low-temperature acid treatment. At a relatively high concentration of 3%, the Huyou fiber showed thermal stability and viscosity similar to those of commercial citrus fiber. When the addition level was below 5%, it improved the cohesiveness and elasticity of the experimental dough and increased the contents of slowly digestible starch and resistant starch. In the in vitro digestion test of bread, the estimated glycemic index of the control group was 78.3 ± 0.8, while that of the group containing Huyou fiber decreased to 68.6 ± 1.0, with a statistically significant difference ($p < 0.05$). Using the same raw material for two or more rounds of product development is more consistent with the idea of cascading by-product utilization than extracting only a single component.

6.3 Utilization models for family farms and small and medium-sized processing entities

Family farms and farmers' cooperatives play different roles from leading processing enterprises in the Huyou industry. Their main strengths are in orchard management, harvesting, fresh fruit sorting, order organization, and direct contact with farmers, rather than investing in high-cost production lines for extracting pectin, flavonoids, or dietary fiber. In 2024, Zou Family Farm shipped a single order of 2 500 kg of Huyou before the Spring Festival and still had another 1 500 kg order to ship that afternoon. Its average daily sales during that period were about 5 000 kg. Since 2017, the farm has adopted a "company + farmers" and "purchase and resale" business model and has established cooperation with four express delivery companies. During the same period, the Changshan Zhongyou Huyou Professional Cooperative shipped about 3 500 kg of Huyou per day. In 2023, the total production of Changshan Huyou was about 145 000 tons, while the total output value of the whole "dual-pomelo" industrial chain centered on Huyou exceeded RMB 4.5 billion.

In 2024, the head of Changshan Hongchun Fruit Professional Cooperative purchased about 200 tons of young green Huyou fruits. After sorting, slicing, and drying, these fruits entered the traditional Chinese medicinal material market for the production of "Qu Zhi Qiao." During the same period, the total local production of dried young green Huyou slices was expected to exceed 6 000 tons. Based on a price of RMB 22 per kilogram, this activity had already developed into an industry worth more than RMB 100 million. Although this case mainly involves young green fruits removed during fruit thinning rather than peel and pomace left after juice processing, its business model provides a useful reference for by-product utilization. Small local business entities do not need to carry out all stages of advanced processing themselves. Instead, they can collect, sort, and conduct simple primary processing of raw materials that were previously low in value or easily discarded, so that these materials meet the specifications required by the next processing stage. The same approach can also be applied to wet Huyou peel and pomace.

7 Analysis of Bottlenecks in the Utilization of Changshan Huyou By-products

7.1 Collection and preservation

The utilization of Changshan Huyou by-products is first limited by seasonal concentration, high moisture content, and rapid spoilage. Citrus processing waste is usually produced mainly during the harvest and processing season. Peel and pomace have a high moisture content and also contain a certain amount of essential oils. If they are not treated in time, fermentation, spoilage, and quality loss can easily occur. The seasonality, high moisture content, and essential oil content of citrus processing waste are important reasons for difficulties in storage and resource utilization (Zema et al., 2018). After Huyou peel and pomace leave the processing line, they should be sorted, dewatered, dried, or stabilized as soon as possible. Otherwise, their potential for further food processing and high-value utilization will be greatly reduced.

Transportation distance can further increase the cost of by-product utilization. A survey of citrus processing enterprises in Italy found that the transportation distance between the place where by-products are generated and the utilization facilities directly affects the treatment methods selected by enterprises (Raimondo et al., 2018). For Changshan Huyou, if peel and wet pomace need to be transported over long distances, their low density and high moisture content can easily make transportation costs higher than the value of the raw materials themselves. Therefore, setting up nearby collection, dewatering, and temporary storage sites in major production areas is more practical than relying only on long-distance transportation to large processing plants.

7.2 Limited product types

Although the types of products developed from citrus by-products have increased, there are still not enough high-value products with stable markets. Citrus by-products can be used to develop food ingredients, pectin, dietary fiber, essential oils, polyphenols, and other functional components. However, in actual production, a large amount of these materials is still used as low-value feed, simple energy materials, or directly disposed of. Cinardi et al. (2025) conducted a life cycle assessment of citrus waste and found that current industries and studies still mainly focus on a limited number of utilization pathways, such as essential oils and energy recovery. This shows that although there are many possible ways to use citrus by-products, a balanced product structure has not yet been fully established.

“Being extractable” does not necessarily mean that a component can become a marketable product. The application of polyphenols from citrus pomace in foods and beverages still faces problems such as strong bitterness, poor water dispersibility, low stability, and limited bioaccessibility. These factors can affect consumer acceptance and product development (Caballero et al., 2022). Therefore, the current priority for Changshan Huyou by-products is not simply to develop more experimental products. Instead, several products with a good market base should be selected and continuously improved, so that a reasonable product structure can be formed among traditional foods, food ingredients, and high-value functional products.

7.3 Limited capacity of small-scale business entities

Family farms, cooperatives, and small processing enterprises are important participants in the Changshan Huyou industry, but their equipment, capital, and technical capacity are limited, making it difficult for them to carry out complicated deep-processing activities independently. Chen et al. (2021) surveyed value-added processing among small-scale agricultural producers and found that limited understanding of food safety regulations, insufficient capital and infrastructure, lack of labor and time, and difficulties in market development were among the most common barriers. These problems are similar to the actual conditions faced by small Huyou processing entities. This also means that not all operators should be expected to enter high-investment fields such as pectin, essential oil, or functional component extraction.

These limitations are not unique to one region. Yusuf et al. (2025) systematically reviewed circular citrus supply chains and identified 128 barriers, among which technological, economic, and information-related barriers were the most important. For Changshan Huyou, small-scale operators are more suitable for fresh fruit grading, peel sorting, Huyou tea production, preserved fruit processing, and other primary processing activities. Pectin, dietary fiber, essential oils, and functional components, which require more advanced equipment and stronger quality control, should be developed by larger enterprises or through cooperation between enterprises and research institutions.

7.4 Insufficient standardization and market development

Whether products made from by-products can achieve stable sales also depends on product standards and consistent quality. Mateus et al. (2023), in their review of citrus by-products for functional foods and active packaging, pointed out that raw material safety, contaminant control, extraction processes, and food safety assessment must all be considered in practical applications. For products such as Huyou tea, peel powder, dietary fiber, and essential oils, large differences in raw material maturity, processing methods, and quality indicators among enterprises can result in inconsistent color, flavor, composition, and stability. This can affect consumers' overall understanding and acceptance of products made from Changshan Huyou by-products.

Market development also cannot rely only on the concept of "resource recycling." Although functional components from citrus by-products have potential applications as food additives and preservation ingredients, their actual use is still limited by cost, sensory properties, addition levels, and safety requirements (Magalhães et al., 2023). The next step in the development of Changshan Huyou by-products should be to gradually establish raw material grades, processing specifications, and product quality indicators. At the same time, packaging, branding, and local characteristics should be strengthened so that by-product products can move from being seen as "reused waste" to normal commercial products that consumers are willing to buy.

7.5 Insufficient coordination across the industrial chain

The utilization of Changshan Huyou by-products involves many participants in cultivation, collection, transportation, processing, research and development, and sales. It is difficult for a single enterprise to complete the whole utilization chain independently. Whether citrus processing enterprises are willing to participate in the joint utilization of by-products depends not only on technical feasibility but also on investment costs, contract duration, risks, transportation distance, and other factors (Raimondo et al., 2018). Industrial chain coordination therefore means more than simply "strengthening cooperation." More importantly, it requires clear decisions about the responsibilities of different participants, raw material supply, product sales, and benefit distribution.

Bishara et al. (2025) included cultivation, processing, juice production, and waste flows in an integrated citrus supply chain design, showing that by-products are more likely to achieve stable utilization when they are planned together with the production and logistics systems of the main products. For Changshan Huyou, a clear division of work can gradually be established: "growers and family farms for raw material production-cooperatives for centralized collection and primary processing-specialized enterprises for deep processing-research institutions for technical support--sales enterprises for branding and marketing." Such a system can connect different levels of by-product utilization and reduce the costs and risks caused by separate development by individual business entities.

8 Development Strategies for Changshan Huyou By-products

8.1 Classified collection and division among business entities

The development of Changshan Huyou by-products should first begin with classified collection during processing. Peel, pomace, seeds, and other residues differ clearly in moisture content, composition, and possible uses. If all these materials are mixed together, their potential for further food processing, food ingredient development, and high-value utilization will be reduced. Therefore, separate collection areas for peel, pomace, and seeds can be set up during juice, preserved fruit, and tea beverage processing. Raw materials that cannot be processed immediately should be dewatered, dried, or temporarily stored at low temperatures. For fruit by-products, proper stabilization, storage, and transportation management are important for improving their utilization in food products (Hasan et al., 2024).

Different business entities should also choose suitable processing levels according to their own conditions. Family farms and cooperatives can focus on specialty foods with relatively low technical requirements, such as Huyou tea, preserved fruit, jam, and fruit cakes. Enterprises with suitable processing equipment can develop pectin, dietary fiber, and peel powder. Leading enterprises can cooperate with universities and research institutions to develop flavonoids, essential oils, and other high-value products. This division can prevent all business entities from blindly pursuing high-technology processing and allow enterprises of different sizes to participate in Huyou by-product utilization.

8.2 Graded processing and cascading utilization

The development of Changshan Huyou by-products should not focus only on one high-value product. Instead, different processing levels should be selected according to raw material quality and available technologies. High-quality peel and pomace can first be used to produce Huyou tea, preserved fruit, jam, and other foods. Raw materials suitable for further processing can be used to produce pectin, dietary fiber, and food powders, while higher-quality peel can be further processed into essential oils and functional components. Studies on the circular economy suggest that agricultural by-products can achieve better overall utilization when processing moves from the recovery of a single product toward the combined development of multiple products (Panwar et al., 2021).

Therefore, Changshan Huyou can gradually develop a cascading processing model based on "multiple uses from one fruit." Food utilization should be given priority, followed by the development of food ingredients and functional products, while the remaining residues can finally be used for feed, compost, or other agricultural purposes. Studies on the biorefinery of fruit processing by-products have emphasized that the combined development of multiple products can improve the overall utilization efficiency of raw materials more effectively than the recovery of only one high-value component (Błaszczyk et al., 2024). For the Huyou industry, this model is more suitable for the actual operating conditions of local enterprises than investing only in complicated high-end extraction projects.

8.3 Collaborative commercialization and regional branding

Turning Huyou by-products from experimental research into commercial products requires stable cooperation among enterprises, research institutions, and agricultural technology extension organizations. Enterprises have a better understanding of raw material supply, production costs, and market demand, while universities and research institutions can provide technical support for pectin extraction, dietary fiber processing, essential oil production, and product quality evaluation. Industry-university-research cooperation can reduce the pressure on small and medium-sized enterprises to independently bear research, development, and equipment costs, while also helping mature technologies enter actual production more quickly.

At the same time, by-product products should not be marketed only as "waste utilization" products but should be developed together with the regional brand of "Changshan Huyou." Citrus by-products are gradually moving from traditional feed and energy uses toward higher-value applications such as biomaterials, food ingredients, and bioactive products (Olmedo-Galarza et al., 2025). In Changshan, Huyou tea, preserved fruit, high-fiber foods, pectin, and functional ingredients can be included under a unified regional brand system. Features such as "origin in Changshan, whole-fruit utilization, green processing, and circular agriculture" can be highlighted to improve consumer acceptance and increase the added value of these products.

8.4 Whole-fruit utilization chain

From the perspective of industrial development, Changshan Huyou should eventually establish a whole-fruit utilization chain covering "cultivation-fresh fruit sales-food processing–by-product processing-high-value products-agricultural reuse of residues." Huyou fruits with good commercial quality should first enter the fresh fruit market, while lower-grade fruits and fruits intended for processing can be used for juice, preserved fruit, and tea beverages. The resulting peel and pomace can then be further used to develop foods, pectin, dietary fiber, essential oils, and functional ingredients. In this way, the value of Huyou will no longer depend only on a single fresh fruit sale or one round of juice processing.

The remaining materials after processing can be used for feed, composting, and agricultural recycling according to their quality and local conditions. Regional studies on agricultural by-products have suggested that orange processing waste can first be used as feed, with the remaining materials then used for composting, forming a cascading utilization and nutrient recycling system (Cinardi et al., 2026). A similar approach can be applied to the Changshan Huyou industry. By connecting Huyou cultivation, processing, by-product development, and reuse in orchards, a regional circular system can gradually be established in which resources "come from the Huyou industry and return to the Huyou industry."

9 Summary and Future Prospects

With the continued development of fresh-fruit marketing and the processing industry of Changshan Huyou, substantial quantities of peel, pomace, seeds, segment membranes, and other processing by-products are generated in a relatively concentrated manner. Huyou peel and pomace still contain valuable components such as pectin, dietary fiber, volatile compounds, and flavonoids. Depending on raw-material quality and processing conditions, these materials can be utilized in traditional foods such as Huyou tea, candied products, jams, and fruit cakes, as well as in the development of pectin, dietary fiber, essential oils, and functional food ingredients. Seeds and other minor by-products can also be separately collected and further utilized. Considering the actual processing capacities of family farms, farmers' cooperatives, and enterprises of different scales, the utilization of Changshan Huyou by-products should not rely exclusively on technically complex and capital-intensive processing. Instead, a cascaded utilization model should be established, in which higher-quality materials are preferentially directed to food and food-ingredient production, suitable raw materials are further processed into higher-value-added products, and the remaining residues are eventually returned to agricultural production through feed utilization, composting, organic fertilizer production, and other appropriate pathways.

In the future, the valorization of Changshan Huyou processing by-products should place greater emphasis on practical outcomes characterized by the ability to process, manufacture, and market products effectively. First, classified collection systems for peel, pomace, and seeds should be improved, together with preliminary treatment facilities for dehydration, drying, and low-temperature temporary storage, so as to reduce raw-material losses caused by deterioration during the concentrated processing season. Second, a differentiated division of processing activities should be established according to the capacities of different business operators. Family farms and farmers' cooperatives may focus on relatively low-investment specialty foods such as Huyou tea, candied products, jams, and fruit cakes; medium-sized processing enterprises may concentrate on food ingredients such as peel powder, pectin, and dietary fiber; and leading enterprises may cooperate with universities and research institutions to develop essential oils, flavonoids, and functional food ingredients. Such differentiated development can help prevent small-scale operators from making inappropriate investments in high-cost processing projects. At the same time, standards for raw-material grading, processing practices, and product quality should be gradually established, while products derived from Huyou by-products should be integrated with the regional brand of "Changshan Huyou," e-commerce channels, and the local specialty agricultural industry. In the long term, the utilization of Changshan Huyou should shift from a model dominated by fresh-fruit and juice production toward whole-fruit utilization. A more complete industrial chain should be developed so that peel, pomace, and other processing residues can be transformed from materials requiring disposal into new production inputs. This transition can reduce resource waste, increase the economic returns of processing enterprises and growers, and ultimately establish a circular utilization model for Changshan Huyou that reflects local characteristics and is accessible to grassroots agricultural operators.

Acknowledgements

The author conducted this study, including literature review, data analysis, and the drafting and revision of the manuscript. The author has read and approved the final version of the manuscript.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Akhter M., Sarkar S., Sharmin T., and Mondal S.C., 2024, Extraction of pectin from powdered citrus peels using various acids: An analysis contrasting orange with lime, Applied Food Research, 4(2): 100614.
https://doi.org/10.1016/j.afres.2024.100614

Bishara S., Harraz N., Elwany H., and Fors H., 2025, Optimizing resilient sustainable citrus supply chain design, Logistics, 9(2): 66.
https://doi.org/10.3390/logistics9020066

Błaszczyk A., Sady S., Pachołek B., Jakubowska D., Grzybowska-Brzezińska M., Krzywonos M., and Popek S., 2024, Sustainable management strategies for fruit processing byproducts for biorefineries: A review, Sustainability, 16(5): 1717.
https://doi.org/10.3390/su16051717

Caballero S., Li Y.O., McClements D.J., and Davidov-Pardo G., 2022, Encapsulation and delivery of bioactive citrus pomace polyphenols: A review, Critical Reviews in Food Science and Nutrition, 62(29): 8028-8044.
https://doi.org/10.1080/10408398.2021.1922873

Caggia C., Palmeri R., Russo N., Timpone R., Randazzo C.L., Todaro A., and Barbagallo S., 2020, Employ of citrus by-product as fat replacer ingredient for bakery confectionery products, Frontiers in Nutrition, 7: 46.
https://doi.org/10.3389/fnut.2020.00046

Chakraborty S., Goel K., Rasal V., Paul K., and Mandal D., 2025, A comprehensive review: Exploring bioactive compounds of citrus fruit peels for therapeutic and industrial applications, Food Science and Engineering, 6(1): 54-69.
https://doi.org/10.37256/fse.6120254847

Chen H., Ellett J.K., Phillips R., and Feng Y., 2021, Small-scale produce growers' barriers and motivators to value-added business: Food safety and beyond, Food Control, 130: 108192.
https://doi.org/10.1016/j.foodcont.2021.108192

Chen L., Wu Y., Jiang X., Gan D., Fan J., Sun Y., Liu W., and Li X., 2023, Dietary fiber extraction from citrus peel pomace: Yield optimization and evaluation of its functionality, rheological behavior, and microstructure properties, Journal of Food Science, 88(8): 3507-3523.
https://doi.org/10.1111/1750-3841.16702

Cinardi G., D'Urso P.R., and Arcidiacono C., 2026, Strategies for wine, orange processing and olive oil by-product valorisation based on GIS spatial analysis, AgriEngineering, 8(1): 25.
https://doi.org/10.3390/agriengineering8010025

Cinardi G., D'Urso P.R., Cascone G., and Arcidiacono C., 2025, Citrus waste valorisation processes from an environmental sustainability perspective: A scoping literature review of life cycle assessment studies, AgriEngineering, 7(10): 335.
https://doi.org/10.3390/agriengineering7100335

Consoli S., Caggia C., Russo N., Randazzo C.L., Continella A., Modica G., Cacciola S.O., Faino L., Reverberi M., Baglieri A., Gennari M., and Barbagallo S., 2023, Sustainable use of citrus waste as organic amendment in orange orchards, Sustainability, 15(3): 2482.
https://doi.org/10.3390/su15032482

Corea-Guillen E.E., Benaouda M., Ramirez-Perez A.H., Lizarazo A.C., Castro-Montoya J.M., Vieyra-Alberto R., and Angeles-Hernandez J.C., 2025, Effect of dietary citrus pulp on performance and dry matter digestibility in dairy cows: A meta-analysis and meta-regression, Animal Feed Science and Technology, 320: 116198.
https://doi.org/10.1016/j.anifeedsci.2024.116198

Gao L., Zhang H., Yuan C.H., Zeng L.H., Xiang Z., Song J.F., Wang H.G., and Jiang J.P., 2022, *Citrus aurantium* 'Changshan-huyou'-An ethnopharmacological and phytochemical review, Frontiers in Pharmacology, 13: 983470.
https://doi.org/10.3389/fphar.2022.983470

Gu Y., Lv J., Gouda M.M., Zhu Y.Y., He Y., and Chen J., 2024, Using pectinase enzymatic peeling for obtaining high-quality Huyou (Citrus changshanensis) segments, Journal of Food Composition and Analysis, 125: 105706.
https://doi.org/10.1016/j.jfca.2023.105706

Hasan M.M., Islam M.R., Haque A.R., Kabir M.R., Khushe K.J., and Hasan S.M.K., 2024, Trends and challenges of fruit by-products utilization: Insights into safety, sensory, and benefits of the use for the development of innovative healthy food: A review, Bioresources and Bioprocessing, 11(1): 10.
https://doi.org/10.1186/s40643-023-00722-8

He Y., Zhu Y., Lv J., Gu Y., Wang T., and Chen J., 2023, Effects of lactic acid bacteria fermentation on the bioactive composition, volatile compounds and antioxidant activity of Huyou (*Citrus aurantium* 'Changshan-huyou') peel and pomace, Food Quality and Safety, 7: fyad003.
https://doi.org/10.1093/fqsafe/fyad003

Hu Y., Li H., Yin K., Chen J., and Wang F., 2026, Status quo and trend of development of comprehensive resource utilization of citrus by-products, Journal of Future Foods, 6(6): 1080-1098.
https://doi.org/10.1016/j.jfutfo.2024.10.014

Huang J., Zhou X., Wang H., Huang Q., Li J., Zeng C., Wang W., and Liu D., 2026, Flavor improvement in enzymatically hydrolyzed Citrus Huyou peel residues: Based on sensory and multi-omics analysis, Food Chemistry, 500: 147337.
https://doi.org/10.1016/j.foodchem.2025.147337

Huang J.Y., Liao J., Qi J.R., Jiang W.X., and Yang X.Q., 2021, Structural and physicochemical properties of pectin-rich dietary fiber prepared from citrus peel, Food Hydrocolloids, 110: 106140.
https://doi.org/10.1016/j.foodhyd.2020.106140

Jadhav V., Kshirsagar R.B., Giri S., and Gorrepati K., 2025, Functional herbal teas from fruit peels: A flavourful solution to food waste, European Journal of Nutrition & Food Safety, 17(8): 165-173.
https://doi.org/10.9734/ejnfs/2025/v17i81808

Kaur S., Panesar P.S., Chopra H.K., and Singh V., 2025, Exploring the bioactive potential of Citrus reticulata pomace: Extraction, characterization, and applications, Food and Humanity, 5: 100518.
https://doi.org/10.1016/j.foohum.2025.100518

Kumar S., Konwar J., Purkayastha M.D., Kalita S., Mukherjee A., and Dutta J., 2023, Current progress in valorization of food processing waste and by-products for pectin extraction, International Journal of Biological Macromolecules, 239: 124332.
https://doi.org/10.1016/j.ijbiomac.2023.124332

Li L., Zhang M., Chitrakar B., and Jiang H., 2020, Effect of combined drying method on phytochemical components, antioxidant capacity and hygroscopicity of Huyou (Citrus changshanensis) fruit, LWT - Food Science and Technology, 123: 109102.
https://doi.org/10.1016/j.lwt.2020.109102

Lu Y., Zhang C., Bucheli P., and Wei D., 2006, Citrus flavonoids in fruit and traditional Chinese medicinal food ingredients in China, Plant Foods for Human Nutrition, 61(2): 57-65.
https://doi.org/10.1007/s11130-006-0014-8

Magalhães D., Vilas-Boas A.A., Teixeira P., and Pintado M., 2023, Functional ingredients and additives from lemon by-products and their applications in food preservation: A review, Foods, 12(5): 1095.
https://doi.org/10.3390/foods12051095

Maqbool Z., Khalid W., Atiq H.T., Koraqi H., Javaid Z., Alhag S.K., Al-Shuraym L.A., Bader D.M.D., Almarzuq M., Afifi M., and Al-Farga A., 2023, Citrus waste as source of bioactive compounds: Extraction and utilization in health and food industry, Molecules, 28(4): 1636.
https://doi.org/10.3390/molecules28041636

Mateus A.R.S., Barros S., Pena A., and Sanches-Silva A., 2023, The potential of citrus by-products in the development of functional food and active packaging, Advances in Food and Nutrition Research, 107: 41-90.
https://doi.org/10.1016/bs.afnr.2023.06.001

Munir H., Yaqoob S., Awan K.A., Imtiaz A., Naveed H., Ahmad N., Naeem M., Sultan W., and Ma Y., 2024, Unveiling the chemistry of citrus peel: Insights into nutraceutical potential and therapeutic applications, Foods, 13(11): 1681.
https://doi.org/10.3390/foods13111681

Negrea M., Cocan I., Jianu C., Alexa E., Berbecea A., Poiană M.A., and Silivasan M., 2025, Valorization of citrus peel byproducts: A sustainable approach to nutrient-rich jam production, Foods, 14(8): 1339.
https://doi.org/10.3390/foods14081339

Núñez-Pérez J., Burbano-García J.L., Espin-Valladares R.C., Lara-Fiallos M.V., DelaVega-Quintero J.C., Cevallos-Vallejos M., and Pais-Chanfrau J.M., 2026, Cascade valorisation of lemon-processing residues (Part I): Current trends in green extraction technologies and high-value bioactive recovery, Foods, 15(3): 491.
https://doi.org/10.3390/foods15030491

Olmedo-Galarza V., Pinto-Mosquera N., Pineda-Flores H., and Manosalvas-Quiroz L., 2025, Citrus waste valorization: Unconventional pathways for sustainable biomaterials and bioactive products, Sustainability, 17(24): 10887.
https://doi.org/10.3390/su172410887

Panwar D., Saini A., Panesar P.S., and Chopra H.K., 2021, Unraveling the scientific perspectives of citrus by-products utilization: Progress towards circular economy, Trends in Food Science & Technology, 111: 549-562.
https://doi.org/10.1016/j.tifs.2021.03.018

Peng Q., Zhang Y., Zhu M., Bao F., Deng J., and Li W., 2024, Polymethoxyflavones from citrus peel: Advances in extraction methods, biological properties, and potential applications, Critical Reviews in Food Science and Nutrition, 64(16): 5618-5630.
https://doi.org/10.1080/10408398.2022.2156476

Raczkowska E., and Serek P., 2024, Health-promoting properties and the use of fruit pomace in the food industry-A review, Nutrients, 16(16): 2757.
https://doi.org/10.3390/nu16162757

Raimondo M., Caracciolo F., Cembalo L., Chinnici G., Pecorino B., and D'Amico M., 2018, Making virtue out of necessity: Managing the citrus waste supply chain for bioeconomy applications, Sustainability, 10(12): 4821.
https://doi.org/10.3390/su10124821

Redha A.A., Yücetepe A., and Esatbeyoglu T., 2026, Impact of drying technologies on bioactive composition of fruit pomace: A critical review and future perspectives, Food Chemistry: X, 36: 103929.
https://doi.org/10.1016/j.fochx.2026.103929

Sanli I., Ozkan G., and Şahin-Yeşilçubuk N., 2025, Green extractions of bioactive compounds from citrus peels and their applications in the food industry, Food Research International, 212: 116352.
https://doi.org/10.1016/j.foodres.2025.116352

Selvaprasad D.E.J., Hegde K.R., Somasundaram K.D., and Manickam L., 2025, Recent advancements in citrus by-product utilization for sustainable food production, Food Biomacromolecules, 2(3): 377-389.
https://doi.org/10.1002/fob2.70022

Singhal S., and Swami Hulle N.R., 2022, Citrus pectins: Structural properties, extraction methods, modifications and applications in food systems - A review, Applied Food Research, 2(2): 100215.
https://doi.org/10.1016/j.afres.2022.100215

Stavrakakis I., Melidis P., Kavroulakis N., Goliomytis M., Simitzis P., and Ntougias S., 2025, Bioeconomy-based approaches for the microbial valorization of citrus processing waste, Microorganisms, 13(8): 1891.
https://doi.org/10.3390/microorganisms13081891

Suri S., Singh A., and Nema P.K., 2021, Recent advances in valorization of citrus fruits processing waste: A way forward towards environmental sustainability, Food Science and Biotechnology, 30(13): 1601-1626.
https://doi.org/10.1007/s10068-021-00984-y

Suri S., Singh A., and Nema P.K., 2022, Current applications of citrus fruit processing waste: A scientific outlook, Applied Food Research, 2(1): 100050.
https://doi.org/10.1016/j.afres.2022.100050

Wang H., Zhou X., Deng Y., Zhang R., Fu K., Huang J., Huang Q., Zeng C., Liu D., and Wang W., 2024, Variations in volatile components and biological activities of essential oils from *Citrus aurantium* 'Changshanhuyou' at different growth and ripening stages, Food Research International, 197(Pt 2): 115303.
https://doi.org/10.1016/j.foodres.2024.115303

Wu J., Tian Y., Wu Z., Weng P., and Zhang X., 2021, Effects of pretreatment with dimethyl dicarbonate on the quality characteristics of fermented Huyou juice and storage stability, Journal of Food Processing and Preservation, 45: e15343.
https://doi.org/10.1111/jfpp.15343

Yusuf H., Fors H., Galal N.M., Elhabashy A.E., Melkonyan A., and Harraz N., 2025, Barriers to implementing circular citrus supply chains: A systematic literature review, Journal of Environmental Management, 373: 123963.
https://doi.org/10.1016/j.jenvman.2024.123963

Zayed A., Badawy M.T., and Farag M.A., 2021, Valorization and extraction optimization of Citrus seeds for food and functional food applications, Food Chemistry, 355: 129609.
https://doi.org/10.1016/j.foodchem.2021.129609

Zema D.A., Calabrò P.S., Folino A., Tamburino V., Zappia G., and Zimbone S.M., 2018, Valorisation of citrus processing waste: A review, Waste Management, 80: 252-273.
https://doi.org/10.1016/j.wasman.2018.09.024

Zhang X., Huang Y., Niu Y., Sun J., Zhang M., Zhang L., and Liu Z., 2025a, Optimized recovery of essential oils from citrus peels using cellulase-salt pretreatment and microwave hydrodistillation: A study of yield and functional activities, LWT, 231: 118369.
https://doi.org/10.1016/j.lwt.2025.118369

Zhang Y., Zhang M., Guo C., Cheng H., Ye X., Chen S., and Chen J., 2025b, Citrus fiber derived from Huyou processing waste and its application in the lower glycemic index bread, Journal of Food Science, 90(11): e70630.
https://doi.org/10.1111/1750-3841.70630

Zhou X., Wang J., Wang H., Lu P., Huang Q., Huang M., Lv R., Liu D., and Wang W., 2024, Identification of extracted antioxidants from *Citrus aurantium* 'Changshanhuyou' residue against digestive enzyme activities and airway smooth muscle cells proliferation using UPLC-MS/MS, Food Bioscience, 61: 104910.
https://doi.org/10.1016/j.fbio.2024.104910

Disclaimer/Publisher's Note

The statements, opinions, and data contained in all publications are solely those of the individual authors and contributors and do not represent the views of the publishing house and/or its editors. The publisher and/or its editors disclaim all responsibility for any harm or damage to persons or property that may result from the application of ideas, methods, instructions, or products discussed in the content. Publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.