Industry note: Resource utilisation note of agricultural and food manufacturing tailings or waste for innovative health product development

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1 Transformation and deformation of agricultural and food processing waste

For promoting the resources circulation and sustainable development of economy, it is necessary to innovative develop into useful product in agricultural and food processing waste resource recovery (Schieber et al., 2001). With the advent of an aging society worldwide, the demand for health products that are beneficial to human health is increasing. Natural plants and food are often used as raw materials for health products. However, environmental and climatic factors have caused food shortages, and we must pay attention to the effective use of agricultural and food processing waste.

Inventions can be made in three ways: novelty, combination and transformation or deformation. Many agricultural or aquaculture wastes and scraps can be developed into valuable products using the resourcefulness of inventions. One of the most common uses is by transformation, transforming useless waste into useful health products. In the process of processing agricultural and fishery products into food, many scraps or wastes are generated. In order to transform agricultural waste into useful products, even

high-value health products, it is necessary to master the efficient extraction and concentration of indicator active substances and the stability of the subsequent finished products. The main consideration in the design concept of developing waste into health products is to analyse what health active substances are present in the waste? What reaction will happen during the manufacturing process? What kind of product form or pharmaceutical form can be made to maintain its stability? This paper reviews our ideas and three commercial examples of converting agricultural and fishery waste into health food or health care products.

2 Health materials in waste of fruit peel, flower and seed

Edible plant-based agricultural products often produce waste and residues during food processing. However, these scraps that are not treated as food can actually be reused as raw materials for health food and pharmaceutical products. In addition to the pulp, the flowers, leaves, peels and seeds of plants are usually rich in natural antioxidants, especially phytochemicals of polyphenols (Lin et al., 2012a, 2012b, 2012c). Polyphenolic compounds have been reported to lower oxidative stress and possess beneficial effects on chronic inflammatory diseases associated with reactive oxygen species (Urquiaga and Leighton, 2000; Pandey and Rizvi, 2009).

Citrus fruits are the largest produced fruit of the world and a large portion is consumed as juice. However, citrus fruits have a small edible portion and consequently, a considerable amount of waste are formed from juice processing plant. Although citrus fruit juice contain vitamin C and phytochemicals and have numerous physiological activities (Murakami et al., 2000; Mothershaw and Jaffer, 2004; Vitali et al., 2007), the waste, which comprise mainly citrus peels and exhibit potent antioxidant and anti-inflammatory activities, would be an exploitable natural resource of functional components (Tripoli et al., 2007; Fernandez-Lopez et al., 2004). In Taiwan, dried citrus peels are usually infused by boiling water and consumed as a health-promoting beverage to treat indigestion and reduce phlegm. The peroxynitrite-scavenging activities of nine citrus fruit peels were evaluated as determined by their ability to attenuate the peroxynitrite-mediated nitrotyrosine formation in albumin. The peroxynitrite-scavenging activity of citrus fruit peels was mainly attributed to the phenolics. We concluded that citrus fruit peels, such as ponkan peel, would be useful raw materials for creating new value-added functional products (Ho et al., 2014). Extracts from kumquat peel also showed an inhibiting effect on nitric oxide production in LPS-induced RAW264.7 macrophage. Interestingly, oven-dried peel from citrus fruit and kumquat contained higher total phenolic compound and appeared to be responsible for its antioxidant activity and anti-inflammatory ability (Lin et al., 2008; Ho and Lin, 2008).

The longan (*Dimocarpus longan Lour*), also known as dragon's eye, has been referred to as the little brother of the lychee. Taiwan is one of the main centres of commercial longan production. The flowers and seeds of the longan were regarded as waste for a long time, and failed to be utilised. In agriculture, off-season induction of flowering in longan trees is a desirable economic goal (Manochai et al., 2005). To increase the size and quality of the fruit, an important operation is to remove flower spikes in the cluster. Some longan flowers are sold in local markets and due to their fresh and fruity aroma are mainly used to prepare an infusion that is drunk for pleasure in Taiwan. We found that longan flower extract, enriched polyphenolics included flavonoids

and proanthocyanidins, exhibit prominent anti-oxidative and anti-inflammatory activity (Ho et al., 2007). Plant extracts with high levels of flavonoids and procyanidins have been studied and are regarded as nutritional supplements with cancer preventive characteristics. Longan flower extract treatment inhibited cell proliferation and malignant potential in the colorectal cancer cell lines (Hsu et al., 2010). The cellular mechanism responsible for the inhibitory effect of longan flower extract on the cell was mainly S phase arrest of the cell cycle (Chen et al., 2020). Therefore, proanthocyanidin-rich extract from longan or lychee flower has the potential to be developed as a novel functional food for colorectal cancer. Similarly, longan and lychee seeds have high levels of the polyphenols containing gallic acid, ellagic acid and are highly antioxidant. Longan and lychee seeds extract treatment both anti-proliferative and anti-malignant in colorectal carcinoma cell lines, suggesting its potential as a novel chemopreventive agent for colorectal carcinoma (Chung et al., 2010; Lin et al., 2013; Wu et al., 2015). Longan or lychee flowers and seeds, traditionally used for relieving pain and urinary diseases, have been revealed in our reports to possess rich amounts of polyphenolic species and exhibit strong anti-oxidant activity, and these could be applied for the treatment of cancer (Lin et al., 2012b).

3 Comprehensive utilisation of tea resource and product development

Various fermented tea and its polyphenolic compounds have received increasing attention owing to their antibacterial, antioxidant activities, anti-proliferation, radio-protective and beneficial effect for health (Tsai et al., 2005; Hsu et al., 2012; Lin et al., 2012c, 2014a, 2014b; Ho et al., 2017; Lin et al., 2017). Most work of teas was focus on the manufacturing of high flavour quality tea. However, the utilisation of sub-quality tea or vice tea for other application has seldom been examined. Is the value of tea determined by sensory taste alone? The ‘price’ of many health food products is determined by the concentration of the indicated active ingredients. The ‘price’ of tea is usually determined by the sensory perception of the tea master or the seller. However, the effect that each person feels after drinking a tea may vary according to their own subjective values. Is it possible for consumers to determine the ‘value’ of tea or health products themselves? Furthermore, due to environmental concerns, the cultivation of tea in the highlands is restricted. It is important to develop low to medium altitude teas or vice tea from tea manufacturing that combine health and flavour to increase the value of teas.

Tea extracts are potent antioxidant agents, and their anti-oxidative capacities not only depend on levels of total phenolic compounds, but are also related to the degree of polymerisation of tea polyphenols or their structure (Lin and Liang, 2002; Chuang et al., 2012). Partly fermented teas showed that not lower or even higher than green tea in activity (Lin et al., 2006). Using a sequence membrane ultra-filtration system, we obtained optimal MW tea fractions by separating an oolong vice tea infusion. Teas exert antioxidant and anti-inflammatory effects, and that gallic acid and medium molecular weight polymeric polyphenols might be the components responsible for many of their biological effects (Lin et al., 2014b). We have clearly demonstrated that the antioxidant capacities and biological effects of tea extracts can be fortified and be concentrated when the tea infusion is processed by membrane separation. Membrane-fractionated oolong tea extracts, medium MW especially, exert antioxidant, anti-inflammatory, whitening and

anti-UV effect. Furthermore, membrane-fractionated oolong tea extracts also exhibited antibacterial potency on pathogenic bacteria but not against lactic acid bacteria and they were used for bowl modulation or skin cleaning. Since the characteristics of these fractionated tea extracts were modified in various different ways, this membrane separation technique can be applied to enrich certain types of tea polyphenols in purposive manner, which will allow the preparation of new nutraceutical or cosmeceuticals.

We have been developing various products using sub-quality tea or vice tea for a long time. Tea polyphenols have antioxidant properties and can be used as a fish preservative (Seto et al., 2005). Ice glazing treatment could enhance on the storage quality of the fish fillet. The combination of glazing treatment and adding vice tea extract could greatly increase the storage quality of the frozen fish fillets (Lin and Lin, 2005). Luteolin has an eye health effect, but the taste from marigold flowers is unpleasant. We use catechins-rich and flavourful oriental beauty vice tea with luteolin to produce tablet that can improve flavour and enhance the health activity. We also use oriental beauty tea dregs fermented with yeast after adding sugar to produce a honeyed, fruity tea wine. Black tea fermentate with lactic acid bacteria exhibited anti-bacterial and anti-UVB activity was developed to oral cleaning and sun block products. These inventions suggest what tea variety to choose or how to process them depended on the purpose of tea application development.

4 Mackerel concentrate and fish oil from cannery factory

Mackerel is one of the major fish caught in Taiwan. Its oil was found to contain abundant n-3 polyunsaturated fatty acid (PUFA), ex., EPA and DHA, which have physiological benefits on human. In the process of manufacturing canned fish, the cut fish is first steamed in the unsealed cans. The cooked soup are then poured out and filled with the seasoning sauce, and the cans are finally sealed and sterilised. The cooked soup contains fresh health ingredients, but it is a shame to discard it in this way, as it often causes environmental problems with waste water treatment. We refine the mackerel cooked broth into concentrate, and we also use a simple oil-water separator (Figure 1) to quickly extract the crude fish oil. The water-soluble part of the cooked broth fed in the B tank will enter the A tank, which can be refined into mackerel concentrate. The floating oil will enter the C tank to let the residual water settle down. Then open the valve of D tank to get the crude mackerel oil after water washing.

The mackerel concentrates from cooking juice processed by enzymatic hydrolysis and then treated by high pressure-low temperature concentration. The mackerel concentrates contained abundant low MW peptide, γ-aminobutyric acid (GABA), branched chain amino acids (BCAA) and taurine that related to anti-fatigue activity (Chang et al., 2019). Quality-of-life (QOL) improvement and antihypertensive effect of mackerel concentrate were also proven. Mackerel concentrate may potentially serve as a good source of healthy oligopeptide and could be transformed into novel value-added functional food supplement [Figure 2(a)].

The crude fish oil can be further refined into fish oil by traditional de-acidification, molecular distillation or supercritical fluid extraction. Refined fish oil also highly susceptible to oxidation because of the polyunsatured nature. Stability of fish oil was affected with nature occurring minor components except predominantly triglyceride.

Oxidation could be ascribed to the catalysed activity of metal or the pro-oxidant effect of α-tocopherol (Sun Hwang et al., 1998). To obtain the most oxidative stable fish oil, it is necessary to use an optimal combination of antioxidants while making sure the oil is free of prooxidants. Therefore, natural antioxidants should be added back to refining or highly purified oil for stabilisation. Refined fish oil can be made into soft capsules with the addition of antioxidants, which is the most common form sold commercially today. For application it can be added to infant formula, and can also be made into powdered fish oil (Lin et al., 1993, 2013). The oxidative and thermal stabilities of fish oil have been effectively ameliorated by spray drying microencapsulation. Wall material containing gelatin, sodium caseinate, and maltodextrin provide optimal protection against oxidation (Lin et al., 1995a). Furthermore, inclusion of lecithin and microcrystalline cellulose in the wall formulation further improved encapsulating effectiveness and stability (Lin et al., 1995b). It can also be made into fish oil beads using the orifice method, which can be used as imitation caviar [Figure 2(b)].

Figure 1 Apparatus for obtaining oil from cooked broth of aquatic products (see online version for colours)

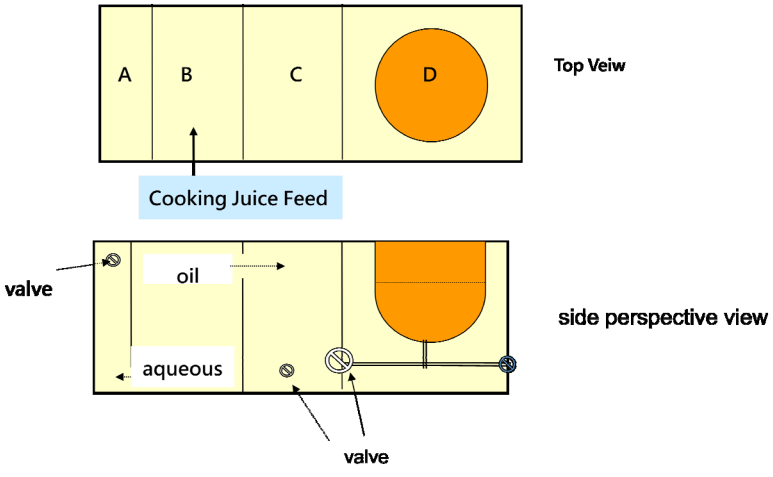

Figure 2 Commercial product, (a) mackerel concentrate (b) mackerel oil bead (see online version for colours)

(a) (b)

5 Future prospects and recommendations

In the issue of agricultural sustainability and human health, this paper suggests that transformation and deformation are the main inventive principles for the use of agricultural wastes in the development of health products. In many agricultural and fishery wastes or food processing scraps and residues, how to recover, extract and concentrate these functional substances such as phytochemicals, vitamins, cellulose, peptides and functional lipidss that are beneficial to human health and produce stable dosage forms that can be transformed into health food or health care products is an issue that needs continuous attention in the future.

Since the final product is a health product, organic solvents cannot be used in the green processing principle. Therefore, usually use water as the solvent. It is also possible to use supercritical fluid extraction. The temperature and time of processing are key control point without destroying the active substances. From development experience, it is known that sometimes proper heating can increase the concentration of the target substance. In addition to stabilised capsule or tablet dosage forms, microencapsulation techniques are sometimes used to make these active substances available for addition to general foods. In summary, the design of a product type or specification is based on marketing access and consumer preferences.

It is worth noting that these functional substances are usually very unstable, so it is important for the industry operation to extract them quickly to keep them fresh and stable. For example, the large amount of soy residue left over from the production of tofu and other soy products contains useful substances such as dietary fibre and soy isoflavones. Since wet soy residue is very perishable and phospholipids are easily oxidised to rancidity, the disposal of soy residue in the past also incurred disposal costs. In Japan, there is drying equipment embedded in tofu factories to quickly dry soy residue on site to become an ingredient for bakery and vegetarian food. In the brewing industry, for example, discarded brewery yeast meal is rich in vitamins, peptides and functional materials (Lin and Wang, 2011). Although much of it is already used in commercial care products, it is expected that after rapid extraction, more resources can be recycled for proper use. Looking ahead, it is worthwhile to keep trying to turn something useless into something valuable.

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