**Research Workshop on Valorisation of Traditional Processing of Indigenous fruit**

**14th - 16th January, 2013, Cambodia**

The Department of Food Technology and Chemical Engineering at Institute of Technology of Cambodia, Phnom Penh, Cambodia and the Centre of Underutilised Crops (CUC) at the University of Southampton are jointly organising a three day (14-16 January, 2013) research planning workshop funded by the Leverhulme Trust, UK. The workshop is focused on promoting cutting edge research and innovation under the project **“International network on preserving safety and nutrition of indigenous fruits and their derivatives”**.

**Workshop objectives:**

* Review cases (from our partner countries) of traditional processing of indigenous or underutilised fruit which may provide the basis for innovative ways of contributing to improvements in local health and nutrition
* Present final results of mini-research projects and conclusions as to what kind of further research is justified
* Highlight the particular research interests and expertise of the Cambodian partner in relation to processing of indigenous fruits
* Identify fundable research gaps that are of interest to two or more network partners and can build on their expertise.
* Draw up an outline of one or more research projects relating to the valorisation of indigenous fruit processing and assign responsibilities for proposal development.

**Workshop venue & accommodation for participants**: Sunway Hotel Phnom Penh, No. 1, Street 92, Sangkat Wat Phnom, Phnom Penh 12202, Kingdom of Cambodia. T +855 23 430 333, F +855 23 430 339.

**Research Workshop Programme**

**Monday (14th Jan 2013)**

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| **Time** | **Session** | **Speakers** |
| 08.30-9.00 | Registration | Dr Hul/Ms Kong |
| 9.00-9.10 | National Anthem & Welcome address | Dr Hul/Ms Kong |
| 9.10-9.20 | Introduction by the participants | Participants |
| 9.20-9.30 | Introduction to the workshop | Dr Kate Schreckenberg |
| 9.30-9.40 | Opening Address | Dr Om Romny, Director General of ITC |
| 9.40-10.10 | Photo Session and Tea Break |  |
| 10.10-10.45  25 min presentation + 10 min discussion | Overview of fruit processing in Cambodia: Current status and future prospects | Dr In Sokneang, ITC, Cambodia  **Suggested Discussants:**  Dr Reynes and Dr Dharmasena |
| 10.45-11.20  25 min presentation + 10 min discussion | Value Addition to Jackfruit *(Artocarpus heterophyllus* Lam.) through Integrated Processing and Preservation | Dr M G Saha and Dr Md Atiqur Rahman ,Bangladesh Agricultural Research Institute  **Suggested Discussants:**  Dr Haq and Dr Phuong |
| 11.20-11.55  25 min presentation + 10 min discussion | Obtention of some carotenoids extract from cashew apple using membrane technology | Dr Max Reynes, CIRAD, France  **Suggested Discussants:**  Dr Schreckenberg and Prof SK Roy |
| 11.55-12.50 | Lunch break |  |
| 12.50-13.25  25 min presentation + 10 min discussion | Valorisation of the vegetal biodiversity for food safety: Characterisation of antimicrobial plant extracts | Dr Samira Sarter, Hanoi University of Science and Technology, Vietnam  **Suggested Discussants:**  Dr Haq and Dr Hul |
| 13.25-14.00  25 min presentation + 10 min discussion | Preservation and quality aspects of selected Sri Lankan fruits | Prof DAN DharmasenaandDr KH Sarananda, Sri Lanka  **Suggested Discussants:**  Dr Schreckenberg and Dr Dwivedi |
| 14.00-14.35  25 min presentation + 10 min discussion | Stability evaluation of anthocyanins obtained from wild Jamun (*Syzygium cumini* Skeels) fruits and their utilization as a food supplement | Dr Shailendra Dwivedi, Amity University, India.  **Suggested Discussants:**  Dr Reynes and Dr Modan Saha |
| 14.35-15.00 | Tea Break |  |
| 15.00-15.35  25 min presentation + 10 min discussion | Integrated Processing of *Jamun* (*Syzygium cumini* Skeels) for value addition and assessment of  its impact on health & nutrition | Prof Susanta Kumar Roy, Amity University, India.  **Suggested Discussants:**  Dr Schreckenberg and Dr Sarter |
| 15.35-16.10  25 min presentation + 10 min discussion | Valorisation of fruits by product for health beneficial components | Dr Pham Huu Yen Phuong and Ms Duong Thi Ngoc Diep Vietnam  **Suggested Discussants:**  Dr Haq and one from Cambodia |
| 16.10-16.45  25 min presentation + 10 min discussion | Wine production from indigenous fruit such as goose berry, jambula, tamarind and mango | Mr Buntong Borarin, Royal University of Agriculture, Cambodia  **Suggested Discussants:**  Dr Reynes and Dr In Sokneang |
| 16.45-17.30 | Discussion on 2-3 key themes to develop into research proposals | **Chair-** Dr Kate Schreckenberg |
| 17.30 | Closure of the first day |  |

**Tuesday (15th Jan 2013)**

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| **Time** | **Session** | **Speakers/Chair** |
| 8.25-9.00  25 min presentation + 10 min discussion | History and product presentation | Mr Hym Piseth, Cofirel Co.Ltd, Cambodia. |
| 9.00-10.00  15 mins for each presentation + discussion  (reports to be circulated in advance) | Presentation of final reports of mini-research projects  -Vietnam  -India  -Bangladesh  -Cambodia | Chair Dr Nazmul Haq |
| 10.00-10.30 | Tea Break |  |
| 10.30- 12.00 | 2-3 Groups working to develop outline project proposals | Group leaders to be determined |
| 12.00-13.00 | Lunch Break |  |
| 13.00-14.30 | Continued work in groups |  |
| 14.30-15.30 | Report back to plenary to obtain feedback from other participants on proposal outlines |  |
| 15.30-16.00 | Tea Break |  |
| 16.00-17.30 | Further work by groups to develop proposals and assign responsibilities for further elements of proposal preparation. |  |
| 17.30 | Closure of the second day |  |

**Wednesday (16th Jan 2013)**

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| 9.00-12.30 | Field Visit (to be confirmed) |  |
| 12.30-13.30 | Lunch break |  |
| 13.30-14.30 | Discussion on dissemination and policy briefings |  |
| 14.30-15.00 | Tea break |  |
| 15.00-16.00 | Finalise the next workshop (Date, venue, topics, participants, budget etc.) | Only the partners |
| 16.00 | Closure of the third day |  |

**List of participants**

|  |  |  |  |
| --- | --- | --- | --- |
| **Country** | **Name of Participant** | **Institute** | **Email** |
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|  | Mr. Sin Sokdavin | Department of Agriculture, K. Cham |  |
| Mr. Buntong Borarin | Royal University of Agriculture | [borarin@yahoo.com](mailto:borarin@yahoo.com) |
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**Abstracts of Papers being presented**

**1. An overview of fresh and processed fruits production in Cambodia**

Dr Seingheng HUL, Institute of Technology of Cambodia

(not yet received)

**2. Value Addition to Jackfruit *(Artocarpus heterophyllus* Lam.) through Integrated Processing and Preservation**

**M.G. Saha and M.A. Rahman,** Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701, Bangladesh

Jackfruit *(Artocarpus heterophyllus* Lam.) belongs to the family Moraceae. It is an important and widely distributed fruit crop in Bangladesh. It ranks top in production among the fruits grown in the country accounting 23.08% of total fruit production in 2008-09. The fruit is very popular to the rural people. It has gained the national fruit of Bangladesh due to its popularity and various features.

The ripe jackfruit is mainly used for its sweet and aromatic bulb (arils), which is rich in carotene, potassium and carbohydrates, moderately rich in ascorbic acid (Rahim and Quddus, 2000; Samaddar, 1985; Hossain et al., 1979). It is also reported to have some minerals like calcium and potassium and Vitamin B like thiamin, riboflavin, and Niacin (Acedo, 1992). The young and tender fruit is used primarily as vegetable that contain high amount of vitamins and minerals. Seed is mainly used in curry, and reported to be more nutritious than the bulb, being richer in protein, fat, potassium and carbohydrate with considerable amount of phosphorus and calcium (Acedo, 1992; Rahim and Quddus, 2000). Thus, the intake of jackfruit and jackfruit products significantly contribute to the nutrition and health benefits of the people of Bangladesh.

The peak harvesting time of jackfruit is June to August in Bangladesh. It’s a hot, humid and rainy period. In this period, marketing of fruit becomes difficult, as the harvested fruits are rotten quickly once it ripens. As a result a substantial amount of jackfruit ruins unsold and ultimately goes waste. The postharvest losses of jackfruit in Bangladesh at grower’s, middleman, wholesalers’ and retailers’ levels were estimated to be 5.2, 7.0, 10.1 and 3.1%, respectively. Thus, the total postharvest loss of jackfruit was 25.4% in the entire supply chain (Molla et al., 2011). The mentioned losses can be minimized by effective postharvest management and processing protocols. Jackfruit has great potential for processing into value-added product. However, the processing techniques of jackfruit are scanty in the country. Nevertheless Jackfruit chips, candy, pickles, leathers, sugar syrup preserves and jackfruit seed powder have been prepared by Bangladesh Agricultural Research Institute (BARI). Protocols for preparing jackfruit biscuit, flake, butter, toffee and powder were developed by Bangladesh Council of Scientific and Industrial Research (BCSIR) (Hossain et al., 2011). Green jackfruit pickle and jackfruit sweet pickle were also prepared (Kibria et al., 2007). But many of the products are not shelf-stable and standard in quality. Moreover, the rate of changes in nutritional value of the products was not precisely determined during storage. Thus, the products developed from jackfruit are needed to be further standardized. Besides, the processing technologies of jackfruits developed by BARI, BCSIR and Universities are not well known by all stakeholders and consumers of the country due to lack of proper linkage. Mainly small and cottage level food processing unit including rural woman are considered as stakeholders in jackfruit processing. It is therefore, needed to disseminate the knowledge to the stakeholder and end users informing nutritional facts and features through modern protocols. In addition, more products can be developed from bulb, rind and seed of jackfruit for full flourishing of its processing potentiality. Initiative may also be taken to prepare jackfruit rind jelly for waste management.

From the above all consideration, the present study seeks to undertake integrated processing of jackfruit and its total utilization as value additions. It is also intended to organize training programmes for small scale processors, entrepreneurs and end users so that the findings can be disseminated among the stakeholders. Another targeted aim of this study would be reduce losses and enhance the availability of the processed products for prolonged consumption. Thus, the study will contribute to help to add extra flavor to diversify dietary food item, preserve safety and nutrition of jackfruit, and creates opportunities to earn income and employment of rural people.

**References**

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**3. Obtention of some carotenoids extract from cashew apple using membrane technology**

Fernado Abreu (Embrapa) – presented by **Dr Max Reynes**, CIRAD, France

Whatever is the area of plantation, cashew (*Anacardium occidentale* L.) is grown primarily for the production of nuts, a supply chain that has great socioeconomic importance, especially in Brazil. The cashew juice is a by-product that results from pressing the nut’s hypertrophied peduncle, known as cashew apple, a juicy pseudo fruit. Peduncle processing generates large volumes of industrial solid waste that are usually discarded or sometimes used as animal feed. In this context, this work aimed to propose and evaluate a new process that provides an added value to this industrial by-product, extracting carotenoids that were contained therein.

The process comprised three successive operations: an extraction by pressing associated to an enzymatic maceration, a cold concentration of the extract by crossflow microfiltration and purification by diafiltration.

The dose of pectinase used during maceration and the applied force used during the pressing operation were the most influential parameters on the carotenoid extract profile. High doses of pectinase associated with a high pressing force led to a richer carotenoid extract and enhanced the density of permeate flux in microfiltration. The use of several successive cycles of compression increased the carotenoid content in the extract but also increased its fouling properties during microfiltration. The extract concentration by crossflow microfiltration study showed that it was possible to reach values of volumetric reduction ratio (VRR) of about 20, maintaining the permeate flux above 100 Lh-1m-2. The carotenoids were concentrated in the same levels of FRV (up to 20 times). The diafiltration allowed purification of carotenoids 5 times in relation to the dry matter. A simple model, based on a mass balance to predict the impact of VRR and diavolume on the extract composition was developed and validated. The final extract obtained presented a carotenoid content of 70 mg kg-1. Among the 11 compounds identified by HPLC-DAD-MS, the main carotenoids were cis and trans isomers of auroxanthine and β-cryptoxanthin. The final extracts obtained were in the form of viscous liquids of a yellow intense color, and easily dispersed in water.

These concentrates have a strong potential for use in the formulation of foods and beverages as a natural dye.

**4. Valorisation of the vegetal biodiversity for food safety: characterisation of antimicrobial plant extracts**

**S. Sarter** and **Chu-Ky Son**, CIRAD-Hanoi University of Science and Technology

The World Health Organisation has targeted antibiotic resistance as one of the major emerging public health concerns that needs a global strategy for its containment. According to the Centres for Disease Control and Prevention (USA), which lead several programmes to monitor antimicrobial resistance of bacteria, resistant strains of three major human pathogens – *Salmonella* spp.*,* *Campylobacter* spp. and *Escherichia coli* – are linked to the use of antibiotics in animal husbandry. Literature has reported that the major route of transmission of resistant microorganisms from animals to humans is through the food chain. Therefore, new active compounds to prevent and to control infectious diseases need to be developed in order to make food producing farming more sustainable and reduce the use of chemicals. In this perspective, plants are generally considered as rich sources of safe and economical active compounds and several studies have been done over the world to characterize the rich biodiversity which is the basis of traditional medicine and local know-how.

For instance in aquaculture, for which Asean countries represent 90% of the global production, we showed that essential oils of *Cinnamosma fragrans* (an endemic tree to Madagascar) have significantly reduced the bacterial load of *Vibrio* spp. population in *in vivo* *Penaeus monodon* larval culture. It has enhanced the survival rate of the larvae as well [1.2.3]. Due to their mode of action affecting several targets, no particular resistance or adaptation to essential oils has been described so far in the literature [4].

The oral communication will show:

* The occurrence of resistant bacteria to antibiotics in the region
* Research results on antimicrobial essential oils and application in shrimp larvae
* Current research with local plant extracts in Vietnam
* Potential to develop a regional project on the characterization of antimicrobial properties of fruits or spices extracts for application in food production or processing

**References:**

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**5. Preservation and quality aspects of selected Sri Lankan fruits**

**Dharmasena, D.A.N.,** Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka

Changes occurring with processing can be desirable or undesirable and can affect the sensory & functional properties, and nutritive value. Development of toxic substances, changes to the texture, flavor, color and nutritive value are some of the undesirable properties. Development of pleasing odors, flavors and textures, inactivation of enzymes and nutritional substances, improvement of the functionality in food ingredients are possible desirable properties. *Garcinia cambogia*, *Citrus aurantifolia* (Lime) and *Tamarindus indica* (Tamarind) are some of the seasonal fruits in Sri Lanka and the preservation is mainly done by indigenous methodsover the years forusingthem throughout the year. The products obtained from indigenous preservation methods lead to a poor quality end products and they are still considered as underutilized crops in Sri Lanka. The common preservation methods currently used are heating, cooling (chilling& freezing), reduction of water activity; concentration& dehydration, and fermentation, have been originally developed with little knowledge of the chemical changes. But the compositional changes with the processing have not being studied sufficiently and there are only few experimental data are published.

The ripen tamarind fruit contains 63-69% pulp as it is rich in moisture (66%) and reduces to 45-55% pulp, 23-30% Brix with a pH of 3.2 after removal of the shell and drying. Fruit contains a variety of pigments. The water soluble anthocyanin pigment is responsible for the colour of the pulp of the red type while in the common variety contains leuco–cyanidin. Colour of the tamarind pulp is generally brownish red. But during storage pulp becomes darker and after about one year, it becomes almost black. This may be due to Millard reaction as the presence of free amino acids and reducing sugars in the pulp. The fruit pulp also contains citric, tartaric, oxalic, malic and succinic acids. An experiment about making a tamarind pellets has shown that the Tamarind pellets increased its solubility by two and half times than the unprocessed tamarind. This experiment has shown an increase of the solubility of the acids in water after making pellets than the dried pod. In a separate study, it was found that the highest drying rate can be obtained after separating the paste from the pod. A study about a development of a wine from tamarind has been conducted and it was found that the antioxidant activity (reference - ascorbic acid) was between 88% - 96%.

Garcinia is a fruit which is too acid in the fresh state and it contains tartaric acid (10.6%), reducing sugars (15%) and phosphoric acid (1.52%). Processing Garcinia cloves into pellets has shown that an increase of the acid content by three times in pellet form than the same weight of its cloves in a solution after boiling. Color observations also have shown an increase in color of the pellets of Garcinia and paste of Tamarind than the same weight Garcinia cloves and tamarind pods after hot water extraction in a water bath.

The drying characteristics and energy use efficiency of whole lime (black lime) under different drying conditions has shown changes in rate of drying with the drying temperature. The equilibrium moisture content has been varied with the drying temperature and the higher the drying temperature, lower the equilibrium moisture content. The titrable acidity and the diameter reduction ratio of hydrated lime were increased with increase in drying temperature. The rate of change of color depends on the drying time and the drying temperature of lime. Color measurement has indicated that greenness decreased with an increase in the drying temperature and darkness increased with an increasing drying temperature. Further the rate of change of color also increased with the moisture content. Considering the export quality standards of hydrated lime, the lime dried at higher temperatures (70 0C and 100 0C) produced black lime which is preferred in Saudi Arabia and the lime dried at lower temperatures (45 0C 600 0C) were more brownish and lighter in color and preferred by other gulf countries.

*Key words: Garcinia, lime, tamarind, processing, preservation, functional quality*

**6. Stability evaluation of anthocyanins obtained from wild Jamun (*Syzygium cumini* Skeels) fruits and their utilization as a food supplement.**

**Shailendra K Dwivedi** and **Vigya Mishra**, Amity International Centre for Post Harvest Technology and Cold Chain Management, Amity University, Noida, India, 201 301

Anthocyanins are pigments found naturally in the plant system. Being functionally active compounds, they are well known for their antioxidant activity and medicinal properties. Because of their diverse physiological activities, the consumption of anthocyanin may play a significant role in preventing lifestyle-related diseases such as cancer, cardiovascular and neurological diseases. Anthocyanins have a long history of being a part of the human diet and are receiving renewed attention as food colourants and antioxidants despite of their chemically unstable nature, difficulties in purification and their commercial non-availability which has been a primary limitation in their utilization at a commercial level.

One of the rich sources of anthocyanins is the fruit of wild *Jamun* (*Syzygium cumini* Skeels) which is hitherto an underutilized subtropical fruit of India. These fruits are small in size with low pulp content and have large seeds. Ripe fruits are deep purple in colour and have been used in traditional medicine systems for curing many chronic problems primarily *Diabetes mellitus*, etc. In spite of being rich in anthocyanins, wild jamun is not generally consumed as a fresh fruit and its consumption for processing purpose is also low due to low pulp content, large seeds and other difficulties in processing. However, *Jamun* fruits can be used as a potential source of anthocyanins for utilization in different food items as colourants and nutrient supplements. Previous reviews have shown that there are no reports on extraction and stability evaluation of anthocyanins from wild *Jamun* fruits and their utilization as food supplement. Similarly, there is no documentation on the clinical studies of anthocyanins extracted from wild *Jamun* fruits. Therefore, wild *Jamun* fruits can be chosen for the study and can be tested for its utilization as a food supplement to replace the synthetic food supplements and food colourants.

The present study has therefore, been proposed to extract and evaluate the stability of wild *Jamun* anthocyanins and to utilize them as food supplement to improve the colour as well as nutritional quality of the processed food products. In the study, anthocyanins extract of wild *Jamun* fruits will be obtained and their stability to light, temperature and pH etc will be evaluated. The extract will be dried and prepared into an uniform powder or will be microencapsulated in standardized encapsulation material. These capsules will therefore be incorporated in different food items like confectionary, dairy products, beverages etc as a nutrient supplement. The improvement in nutritional quality of foods by these supplements will be evaluated in terms of their antioxidant and antimicrobial activities through different trials.

**7. Title: Integrated Processing of *Jamun (Syzgium cumini* Skeels) for value addition and assessment of its impact on health & nutrition**

**Susanta K. Roy** and **Sunil Saran** , Amity International Centre for Post Harvest Technology & Cold Chain Management, Amity University Campus, Sector-125,Expressway, Noida.

Jamun is an important indigenous fruit, which belongs to the family Myrtaceae and is grown widely in different agro-climatic conditions in South Asia but remains underutilized. The ripe fruits are purplish black in colour due to the presence of anthocyanins and have high antioxidant property which contributes to the numerous health benefits of the fruit. Jamun has been reported to be rich in mineral contents especially iron, potassium, sodium and calcium. Jamun seeds are used in traditional medicine. They are reported to be rich in flavonoids and phenolics which halt the diastatic conversion of starch into sugar. The antioxidant activity accounts for scavenging of free radicals and helps to control various ailments.

*Jamun* fruits are of two types, small seeded and large seeded. The small seeded fruits are oblong in shape and have more pulp. Moreover, they have high sugar/acid ratio, low tannins and total anthocyanins and are suitable for the table. The large seeded fruits which generally grow wild and have very little pulp. They are not suitable for the table purpose and are best suited for processing as they contain high amount of acidity, tannins and anthocyanins.

Jamun is highly perishable, therefore, very difficult to store and market at distant places. Processing is the only way to protect the properties of Jamun and make them available for consumption.

Methods have been standardized for the extraction of juices from wild jamun by crushing and pressing the whole fruit. The extracted juice can be used to make various delicious beverages. However, any industry based solely on the extraction of juice from wild jamun will not be highly profitable because the yield of juice is only about 30 – 40%. On the other hand the pomace which is left over after the juice is extracted consists of seed and peel and is very rich in anthocyanins and various other phytochemicals. These can be isolated and used in traditional medicines, thereby adding to its value.

One of the reasons for the fruit processing industry in South Asian Counties not being very viable is non-utilization of waste accumulated during processing. The present study seeks to undertake integrated processing of Jamun and its total utilization as value additions. Estimation of various constituents will also be carried out both in juice and the extracts obtained from pomace at different stages. It is also intended to organize training programmes for entrepreneurs so that the findings can be disseminated among the processors. Another targeted aim of this study would be to reduce losses and enhance the availability of the processed products for prolonged consumption which will facilitate assessment of jamun consumption on health and nutrition.

**8. Valorisation of fruit by-products for health-beneficial components**

**Dr Pham Huu Yen Phuong** and **Ms Duong Thi Ngoc Diep**, Ho Chi Minh City Nong Lam University & SOFRI (Southern Fruit Research Institute)

In recent years, both the surface area for and the yield of fruit and vegetables production in Vietnam has been increasing. For example, in 2007 the production from fruit tree cultivation was 6.5 million metric tonnes and in 2011 the production from 780000 hectares of fruit trees was at ~ 7 million metric tonnes. Although several research attempts were made to increase the shelf life of fresh fruit and vegetables, losses are still high, especially during the harvesting season. By-products such as seeds, rind/peel, core, broken pieces from fruit and vegetable processing are not utilized at their full potentials or not utilized at all.

Consumption of several phenolic compounds is related to reduced risks of several diseases e.g. cardiovascular and Alzheimer disease, diabetes, and strokes. It is well-known that fruits and vegetables are rich sources of these compounds. Furthermore, the waste streams from fruit processing still contain high amounts of minor components with an added value (e.g. phenolic compounds) and are thus considered as cheap sources of bio-active compounds. As these phenolic compounds (are antioxidants) are not easily synthesized chemically, there is a need to explore possibilities of alternative production sources of these phytochemicals. Based on those facts, this project is designed to focus on valorisation of fruit by-products for such health beneficial compounds.

The selection of by-products is based on the following criteria: high production amounts in Southern Vietnam, high amounts of by-products related to the product, both rural and industrial production sites, and not-well investigated products. For example, mangosteen seeds and rind, dragon fruit rind, seeds of longan, rambutan and jackfruits are in the list of consideration. The specific objectives and outline of the proposal are:

*Work Package 1: Characterization of selected by-products*

Five kinds of fruit by-products will be characterised in detail. First, the samples will be characterised by their gross composition (carbohydrate, oil, protein, fibre, mineral), needed to understand the results obtained in the other WPs in a better way. Then, a series of analysis including spectrophotometrical methods for the total concentration of phenolic compounds, antioxidative capacity, and antimicrobial activity will be carried out to evaluate the possibility of using these by-products as sources of bio-active components. Three by-products will be selected for further investigation in the subsequent WPs.

*Work Package 2: Optimization of extraction of the antioxidants*

Phenolic compounds are normally (partly) bound within the matrix of plant materials. Extreme solvents are effective in extracting the antioxidants. However, they are not friendly to the environment and the extract is ‘not suitable’ for human food. Therefore, more environment-friendly solvents such as water and ethanol are preferred even though the extraction efficiency is not comparable. Applications of microwave have been proven to improve the extraction efficiency of phenolic compounds from soft plant tissues such as fruit pulp, leaves, and roots. Research on the application of these techniques on fruit seeds and rind is scarce. The objective of this WP is to investigate the potential assistance of microwave in solid/liquid extractions of the phenolic compounds from the three selected samples. Extraction conditions (e.g. microwave settings, temperatures, time, solvent volumes) will be optimized based on the yield, solvent use, time, and economic aspects.

*Work Package 3: Ultrasound-assisting extraction the antioxidants*

Through a number of reports, the extraction efficiency of phenolic compounds from plant matrixes can be improved by using ultrasound. The objectives and experiment settings of this WP are similar with those of the previous one but the use of ultrasound, instead of microwave, at suitable extraction steps will be investigated.

*Work Package 4: Writing reports and publications*

Reports will be written and submitted at due times according to the requirements. Possible manuscripts will be written for submission.