GUIDELINES ON IMPLEMENTATION AND MANAGEMENT OF SECONDARY PROCESSING SYSTEMS

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Task 4.5: Technological research for secondary processing

Subtask 4.5.1: Centrifugation, filtration, and clarification

Leader: UNIBO
Participants: ENAM, CEFA, GIE

1. Introduction

1.1 Olive milling process

Extra virgin olive oil extraction includes a series of subsequent operations. Briefly, olives are generally washed and milled to obtain the olive paste. Next, the olive paste is kneaded, which is technically called the malaxation phase, and then centrifuged by two/three phase decanters (in case of new systems working in continuous) in order to separate the olive oil from water and solids, i.e. pomace [1].
The temperature is a key factor to be controlled during the milling process; in fact, it can affect both quality characteristics and oil yield [1,2,3]. For example, temperatures above 27°C- (maximum of temperature that can be achieved in case of the use of "cold extraction" facultative terminology on the label) increase lipase enzyme activity, thus determining an increment of the primary oxidation process [2,3]. Also, centrifugation systems could impact the characteristics of the oils. Specifically, using a two-phase decanter instead of a three-phase one, for which a significative amount of water is mixed to the olive paste, the phenolic content can be effectively preserved [4]. Moreover, before bottling, clarification and filtration steps are generally performed. In particular, nowadays, oil clarification is generally carried out by vertical centrifugation or/and natural settling [5]. Then, the virgin olive oil remains cloudy due to partial emulsion between the oil and a small quantity of water (0.5–0.7%), dispersed as microdroplets.
Filtration is performed to eliminate humidity and sediments, but it is possible to bottle the unfiltered oil. However, the cloudy appearance in the unfiltered oils only persists for several months before becoming a separate phase or a deposit, i. e, a brown-coloured residue at the bottom of the bottle [5].
Olive growing is an important component of the agricultural sector and constitutes the main cultivated fruit sector, as it represents 65% [7] of the national arboricultural area. Covering an area of more than 1 million hectares and located in almost the entire national territory (except for the Atlantic coastal strip), the national olive production reached 1.4 million tons in 2019/2020 with an olive oil production of nearly 145,000 tons and 130,000 tons of table olives [8].
The national olive grove is constituted for more than 96%, by the Moroccan picholine population variety which, despite its adaptability and its double purpose (production of oil and olive preserves), presents certain disadvantages, notably a great sensitivity to certain diseases, a strong index of alternation of production and a low content in olive oil (22% against 26 to 30% for the other oil varieties) [7].
At the processing level, the production of olive oil in Morocco is ensured by traditional units (12,000 Maâsras) that crush about 30% of the olive production, the rest of the production (70%) is processed by semi-modern and modern discontinuous units using super-presses and industrial units, employing a continuous system with two or three phases and centrifugation. [9]
Compared to the continuous system, the traditional oil extraction process is discontinuous and commonly practiced by maâsras located in mountainous and isolated areas where there is no

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infrastructure (water and electricity). This leads to significant losses in both the quantity and quality of the olive oil produced.
Olive oil extraction systems are therefore essentially of three types:
- The crushing units which are equipped with presses and which are classified according to the pressure exerted: traditional maâsras units whose pressure is around 100 kg/cm², semi-modern units whose pressure is around 200 kg/cm² and modern units equipped with super-presses which can develop a pressure of 400 kg/cm².
- The crushing units which are equipped with continuous three-phase chains with two centrifugations, the first to separate pomace and oils plus margines and the second to separate oils and margines (the three phases are pomace, margines and oils).
- The crushing units that are equipped with continuous two-phase lines with a centrifuge that allows the separation of the oil and the pomace moistened by the vegetation water coming from the olive.
Generally, it is accepted that the extraction of olive oil in units equipped with 2-phase centrifugation does not alter the quality of the oil produced. The transformation operations take place in a closed environment and are optimised. The extracted oil is rich in natural preservative substances and therefore has a longer shelf life [9]. The clarification of the oil is carried out by natural decantation except for the industrial units whose production is mainly intended for export (vertical centrifugation).

1.2 Objectives and description of the innovation

Objective: The aim of this subtask is to find the best technological solutions in order to obtain high-quality, more stable (less prone to fermentative and oxidative defects) and globally marketable virgin olive oils, including flavoured oils. In this regard, typical Mediterranean food products, i.e. orange, pomegranate and black pepper, have been added during the olive milling process to transfer peculiar sensory and compositional characteristics. Moreover, in view of sustainability, the above-mentioned foods have been added as they are and as by-products (e.g. peel, pomace). In order to reach this primary objective, specific indications (guidelines) are presented here to share a common experimental procedure.

Innovation: Monitoring the operative phases (such as centrifugation, filtration, and clarification) of virgin olive oil production and applying those operating procedures to a co-milling or co-malaxation process to obtain flavoured olive oils, also using food by-products in view of sustainability. The new proposed flavoured olive oils are characterized by the presence of minor compounds responsible for peculiar sensory attributes (as well as for specific antioxidant and healthy activities).

2. Description of small-scale tests and results

2.1 Operative procedure

2.1.1 General indications to be considered for the production of both virgin and flavoured olive oils

- Olives storage time before milling: max 48 h (in small boxes avoiding high temperature and/or humidity)
- Malaxation temperature: max 27°C
- Centrifugation: two-phase decanter (system working in continuous)
- Clarification: static decanting in tank
- Storage: in tank under nitrogen
- Filtration: before bottling (manual system) by small system of filtering

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2.1.2 Specific operating procedures to obtain several flavoured oils

- **Co-milling with black pepper: lab-scale test**
  - Olives + black pepper (1% or 2%)
    (w/w: 1 kg of olives + 10 g or 20 g of black pepper)
    Add the black pepper directly with olives during the milling phase.

- **Co-milling with oranges: lab-scale test**
  - Olives + oranges (entire fruit or juice or by-product)
    (w/w: 1 kg of olives + 150 g of entire oranges)
    (w/w: 1 kg of olives + by-products or juice derived from 350 g of oranges)
    Add the orange/by-product/juice directly with olives during the milling phase.

- **Co-milling with oranges and black pepper: lab-scale test**
  - Olives + orange by-product + black pepper
    (w/w: 1 kg of olives + orange by-product from 350 g of the entire fruit + 10 g of black pepper)
    Add the orange by-product and black pepper directly with olives during the milling phase.

- **Co-malaxation with orange powder: lab-scale test**
  - Olives + orange by-product (peel) powder (available to be purchased here: https://www.amazon.it/Natures-Root-rimuovere-detergenti-antibatteriche/dp/B07TYZT2HC/ref=sr_1_6?__mk_it_IT=%C3%85M%C3%85%C5%BD%C3%95%C3%91&crid=3V7ADBEWLOT42&keywords=polvere+arancia&qid=1668164537&qu=eyJxc2MiOiIyLjQ2IiwicXNhIjoiMS44OCIsInFzcCI6IjAuNjUifQ%3D%3D&sprefix=polvere+aranci%2Caps%2C237&sr=8-6)
    (w/w: 1 kg of olives + 10 g of by-product powder)
    Add the orange by-product powder directly with olive paste during the malaxation phase.
    NB. Store the powder closed, avoiding the direct contact with the air.

- **Co-milling with pomegranate: lab-scale test**
  - Olives + pomegranates (entire fruit or juice or by-product)
    (w/w: 1 kg of olives + 150 g of whole pomegranates)
    (w/w: 1 kg of olives + by-product of juice derived from 350 g pomegranates)
    Add the pomegranate/by-product/juice directly with olives during the milling phase.

- **Co-milling with ginger powder: lab-scale test**
  - Olives + ginger powder (powder obtained from by-products of the processing of ginger)
    1 kg of olives + 10.00 g of ginger powder to obtain 1% concentration (sample UNI_1)
    1 kg of olives + 15.00 g of powder to reach 1.5% concentration (sample UNI_1.5)
    1 kg of olives + 30.00 g of powder to obtain a concentration of 3% (sample UNI_3)

All these experimental procedures have been conducted with a lab-scale milling plant (Abencor® system).

Moreover, an experimental test was also done with a semi-industrial pilot plant (working capacity 150 kg olive per hour), in particular:

- **Co-malaxation with oranges: semi-industrial scale**

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- Olives + orange by-product (peel) powder (available to be purchased here: https://www.amazon.it/Natures-Root-rimuovere-detergenti-antibatteriche/dp/B07TYZT2HC/ref=sr_1_6?__mk_it_IT=%C3%85M%C3%85%C5%BD%C3%95%C3%91&crid=3V7ADBEWLOT42&keywords=polvere+arancia&qid=1668164537&qu=eyJxc2MiOiIyLjQ2IiwicXNhIjoiMS44OCIsInFzcCI6IjAuNjUifQ%3D%3D&sprefix=polvere+aranci%2Caps%2C237&sr=8-6)
  (ratio w/w: 80 kg of olives + 800 g of by-product powder)
  Add the orange by-product powder directly with olive paste during the malaxation phase.
  NB. Store the powder closed, avoiding the direct contact with the air.

2.2 Results

- **Co-milling with black pepper: lab scale**
  ➔ On this flavoured oil, UNIBO did not perform any analyses because of the unpleasant sensory characteristics highlighted by the panel.

- **Co-milling with orange: lab scale**
  Free acidity: 0.26% (entire orange) and 0.39% (orange by-product)
  Total phenolic compounds (by Folin-Ciocalteau reagent): 440.3 mg of gallic acid/kg of oil (olives co-milled with entire oranges) and 357.7 mg of gallic acid/kg of oil (olives co-milled with orange by-product).

  Volatile profiles (SPME-GC-MS):

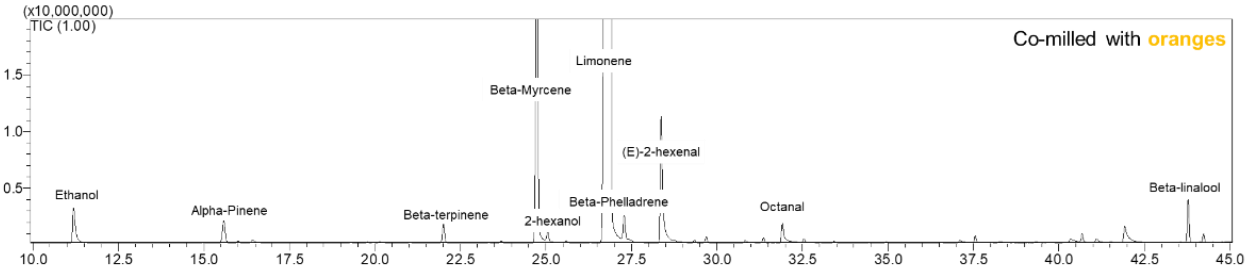

Figure 1. Main volatile compounds of the flavoured oil produced by the co-milling of olives and entire oranges.

Sensory analysis performed by a trained panel for virgin olive oils:
The two samples were characterized by typically positive sensory attributes of virgin olive oils (i.e. fruity, bitter and pungent) as well as by the peculiar orange notes.
In particular, the orange flavour was rated with an intensity of 3.6 (entire oranges) and 3.5 (orange by-product) on a 10 cm unstructured scale (with two anchor points, namely 0, i.e. not perceived, on the left and 10, i.e. extremely strong, on the right). Moreover, only little differences have been noted in relation to the intensity of fruity (1.8 and 2.0, respectively), bitter (3.0 and 3.1, respectively) and pungent (2.5 and 3.0, respectively). For both of the samples no sensory defects have been highlighted.

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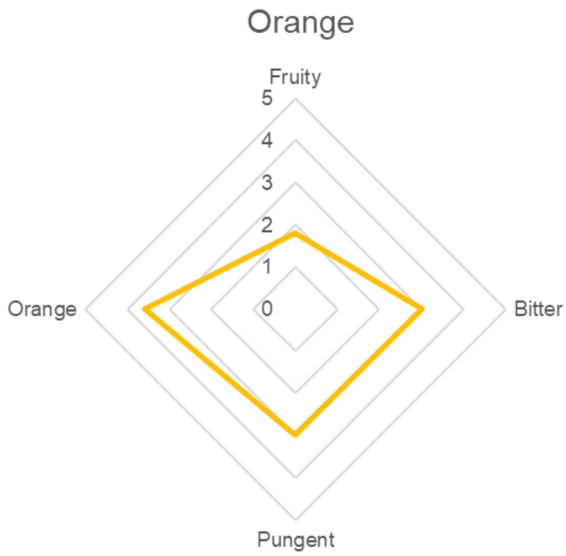

Figure 2. Spider graph of the flavoured oil produced by the co-milling of olives and entire oranges representing the sensory attributes identified by the panel of trained assessors.

- **Co-malaxation with orange by-product powder: lab-scale**

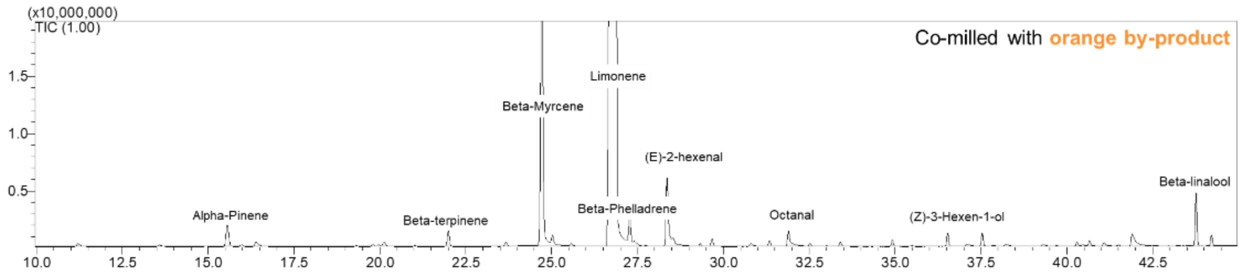

Figure 3. Main volatile compounds of the flavoured oil produced by the co-milling of olives and orange by-product.

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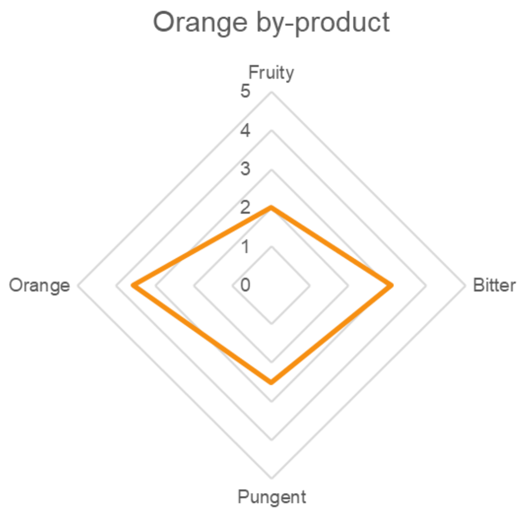

Figure 4. Spider graph of the flavored oil produced by the co-milling of olives and orange by-product representing the sensory attributes identified by the panel of trained assessors.

- **Co-milling with oranges and black pepper: lab scale**
  Free acidity: 0.38%
  Total phenolic compounds (by Folin-Ciocalteau reagent): 656.9 mg of gallic acid/kg of oil
  Volatile profile (SPME-GC-MS):

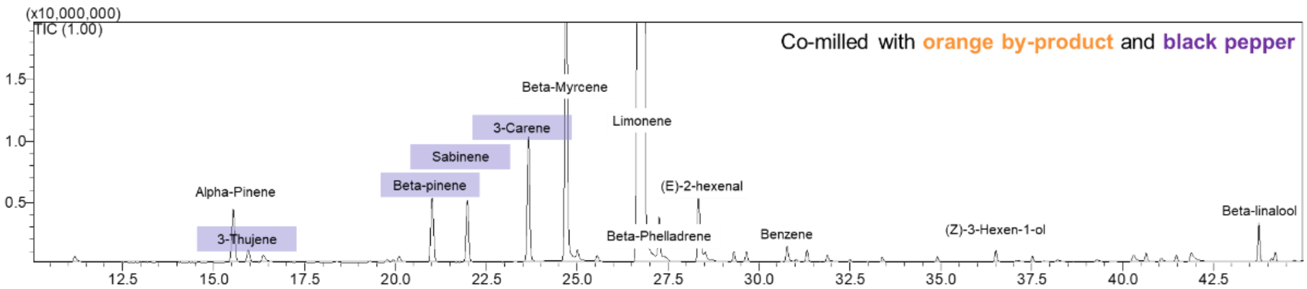

Figure 5. Main volatile compounds of the flavored oil produced by the co-milling of olives and orange by-product+black pepper.

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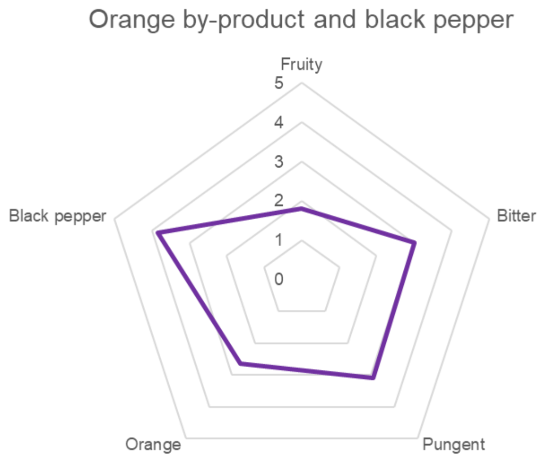

Figure 6. Spider graph of the flavored oil produced by the co-milling of olives, orange by-product and black pepper representing the sensory attributes identified by the panel of trained assessors.

The sample was characterized by typical positive sensory attributes of virgin olive oils and no sensory defects have been highlighted. Sensory notes strictly related to the addition of orange by-product and black pepper have been identified with a sensory intensity of 2.6 and 3.8, respectively. Fruity was rated with an intensity equal to 1.8 on the 10 cm unstructured scale above mentioned, bitter was 3.0 and pungent was 3.1, on the same scale.

- **Co-milling with pomegranate: lab scale**
  ➔ On this flavoured oil, UNIBO did not perform any analyses because of the difficulties to extract the oil due to the formation of emulsions.

- **Co-malaxation with orange by-product powder: semi-industrial scale**

Free acidity of FFO and CS: 0.3%.

Volatile profile analysis (SPME-GC-MS):
he results show the presence of typical compounds of orange such as D-Limonene, β-cis-ocimene and geranyl nitrile. Other compounds related to positive attributes of olive oil (trans-2-hexanal, 2-hexenal, 2-penten-1-ol) were detected. The volatile profile was also characterized by compounds related to negative sensory attributes (acetic acid, 1-tetradecene, 3-pentanone).

Sensory analysis:
The oils have been assessed by the trained panel resulting as virgin olive oils, being characterized by the fusty/muddy as the main perceived defect with median values of intensities of 2.6 (CS) and 2.3 (FFO).

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- **Co-milling with ginger powder: lab scale**

  Analysis of volatile substances by SPME-GC-MS

  In the four figures below the fingerprints of aroma are reported, related to the SPME-GC-MS analysis of samples, in particular: **Figure 7** shows VOCs identified in control sample obtained from Picholine variety olives at low-mill scale, where are present the two main compounds hexanal and (*E*)-2-hexenal derived by LOX pathway and, in comparison in **Figure 8**, the presence of terpenic compounds of ginger (e.g. borneol, zingiberene, curcumene) in FFO at 3% of ginger.

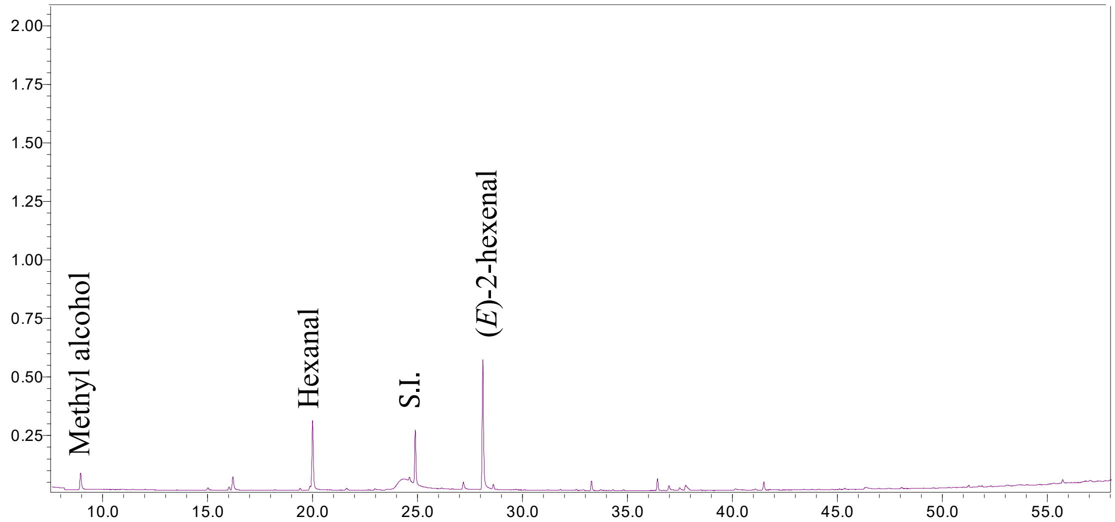

Figure 7

VOCs identified in the control sample obtained from Picholine variety olives at low scale mill.

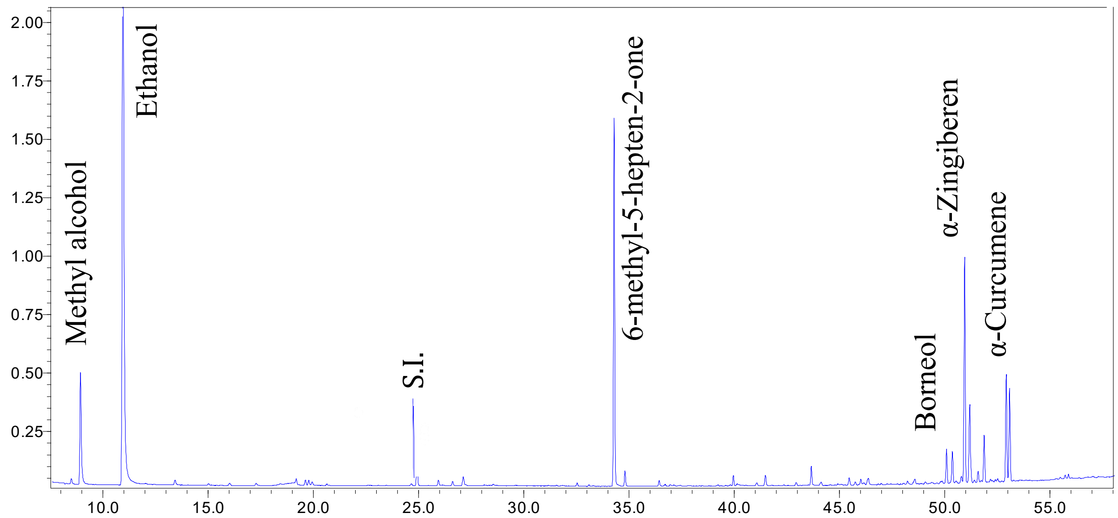

Figure 8

VOCs identified in the sample obtained from Picholine variety olives + 3% ginger powder at low scale mill.

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Sensory analysis

All samples were characterized by only positive attributes (no defects were perceived) and some specific descriptors were related to the presence of ginger as flavoring (e.g. ginger, balsamic/resinous, rosemary/aromatic herbs).

2.3 Protocols for the characterization of virgin and flavoured olive oils

The analyses, and the related analytical methods, for the characterization of virgin and flavoured olive oils are mainly reported in the "standards, methods and guide" (https://www.internationaloliveoil.org/what-we-do/chemistry-standardisation-unit/standards-and-methods/). Also, specific indications for the panel analysis (sensory evaluation) can be found on the International Olive Council (IOC) website in the standard and methods section (https://www.internationaloliveoil.org/what-we-do/chemistry-standardisation-unit/standards-and-methods/).

Moreover, in the EU Regulations 2568/91 and subsequent amendments (last version: Commission Delegated Regulation (EU) 2022/2104 of 29 July 2022, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32022R2104) [6] it is possible to find specific European requirements to be comply for the EU virgin olive oils market.

2.4 Future outcomes

a. Instrumental and sensory analysis have to be carry out on the flavoured oils produced in Morocco at industrial-scale checking samples at time 0 and during the oil storage (e.g. after 3, 6 and 12 months) and checking filtered flavoured oil versus a control sample obtained processing only olives belonging to the same aliquot of olives used for the flavoured oil, in the same day. N.B. it is very important to produce firstly the control sample and then the flavoured olive oil.

2.5 Expected results

a. Production of a flavoured olive oil only by mechanical extraction process with specific compositional and sensory characteristics derived from the flavouring matrix.
b. Re-use and valorisation of food by-products, in order to promote circular economy and sustainability.

3. Risks and mitigation measures

The main risk is related to the limited duration of the harvesting campaign of olives, i.e. from October to January, depending on several factors, e.g. environmental conditions and geographical location. Thus, it is necessary to produce the oils, virgin and/or flavoured, only during these months.

The possible risk related to the addition of the fresh fruit pomace during the milling phase that could cause malfunction of the milling system has been overcoming by adding a pomace powder during the malaxation phase, in order to improve the co-extraction of valuable compounds, avoiding the risks of malfunctions.

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4. Technology and production key performance indicators to be gathered

The guidelines herein presented and the works conducted until now contribute to the achievement of the following KPIs, envisaged in the project grant agreement:

- >10% increase of fresh products shelf-life (average) and reduction of possible sensory defects per relevant innovation (average): in relation to the applied technology a significative enrichment of the oil matrix in peculiar minor bioactive compounds with antioxidant activity and specific flavour, is expected (i.e. contributing to protect the oils from oxidative degradation). Moreover, also in relation to the storage the use of tank and the conservation under nitrogen contribute to preserve the quality of the oils during the shelf-life.
- TPI-ST: >10% reduction of water used per relevant innovation (average): in relation to the use of two-phase decanter to obtain both virgin and flavoured olive oils, which led to the reduction of added water in comparison with a three-phase decanter.
- PPI-ST: >20% reduction of food losses at storage and food waste (average): in relation to the use and valorisation of food by-products (e.g. orange peel) as ingredient for the production of flavoured olive oils, in a view of circular economy and sustainability.

5. Work plan for the validation activities (Subtask 5.5.1)

Selected flavoured oils developed at UNIBO at lab-scale were then produced at industrial scale in Morocco at the beginning of 2023 and at the end of 2024, following the operating procedures described in table below.

At **industrial scale** in Morocco ENAM and GIE Bni Mellal selected every ingredient to be purchased and prepared before processing time for extra virgin and flavoured olive oils.

Orange by-product (peel) powder purchased in https://www.jumia.ma/generic-poudre-decorce-.dorange-250g-48566293.html

- Assure all ingredients must be used on production;
- Support GIE Beni Mellal on production of olive oil and flavoured olive oils;
- Washing before processing any formulation;
- Conduct production of virgin/extra virgin oils before flavoured olive oils;
- Machine description: System working in continuous centrifuged by two phase decanter Production capacity in GIE Ben Mellal;
- Possibility of co-milling;
- Possibility of co-malaxation.

- **Co-malaxation with orange by-product powder: industrial-scale**

The Moroccan samples produced at industrial level showed some problems related to their quality, probably due to non-optimal storage conditions of the Picholine Maroquin olives harvested at the end of the olive oil season (January). This problem masked an effective evaluation of the sensory characteristics related to the type of flavouring agent used. As a consequence of the low quality of FFO (and CS) produced, it was not possible to perform tests on samples stored with and without clarification or filtration.

Therefore, it was necesary to repeat the production during the next olive oil campaign (2023-2024) but harvesting the Picholine Maroquin olives at the beginning of the olive oil season,

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checking the health status of the fruits and storing them before milling in optimal conditions. This is fundamental to improve the quality of the olive oil produced. In addition, ginger as flavouring agent was tested. As a consequence of these corrective actions, a subsequent validation activity of the work plan was carried out (quality of the FFO just produced and of the stored one, after appropriate clarification or filtration steps) producing ginger-flavoured olive oils.

Formulation	Processing	Description
Olives + black pepper (1% or 2%)	**Co-milling**: Add ingredient(s) directly with olives during the milling phase. **Lab-scale tests**	(w/w: 1 kg of olives + 10 g or 20 g of black pepper)
Olives + oranges (entire fruit or juice or by-product)		(w/w: 1 kg of olives + 150 g of entire oranges) (w/w: 1 kg of olives + by-products or juice derived from 350 g of oranges)
Olives + orange by-product + black pepper		(w/w: 1 kg of olives + orange by-product from 350 g of the entire fruit + 10 g of black pepper)
Olives + pomegranates (entire fruit or juice or by-product)		(w/w: 1 kg of olives + 150 g of whole pomegranates) (w/w: 1 kg of olives + by-product of juice derived from 350 g pomegranates)
Olives + orange by-product (peel) powder	**Co-malaxation**: Add the orange by-product powder directly with olive paste during the malaxation phase **Lab-scale test and Semi-industrial scale test**	(w/w: 1 kg of olives + 10 g of by-product powder) Lab scale
		(w/w: 100 kg of olives + 1 Kg of by-product powder) Semi-industrial scale
Olives Picholine Marcaine + orange by-product (peel) powder	**Co-malaxation**: Add the orange by-product powder directly with olive paste during the malaxation phase **Lab scale test**	(w/w: 100 kg of olives + 1 Kg of by-product powder) Lab scale

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Subtask 4.5.2: Juicing, extraction, and fortification

Leader: UoN
Participants: UNIBO, TAM

1. Introduction

Food and nutrition insecurity remains a major challenge in sub-Saharan Africa, Kenya included. It is important to ensure that the local population consumes foods that provide not only adequate protein and energy but also minerals, vitamins and other valuable phytochemicals. A wide variety of fruits and vegetables are cultivated in sub-Saharan Africa. Apart from their energy and fibre contents, fruits and vegetables are particularly rich in micronutrients and other bioactive components. Tree tomato (tamarillo) is grown in Nyeri County of Kenya where the Mukurweini Food Hub is found. It low in simple sugars and rich in minerals, vitamins and other bioactive compounds. It can therefore be to enrich fruit juices for pre-diabetic and diabetic people.

Suitable technologies for fruit juicing (pulping) with regard to product yield, quality, and safety will be tested in order to find the best process applicable in the local framework. The obtained fruit juices will be mixed with other ingredients to formulate and nutritionally enrich novel foods (i.e. therapeutic mixed fruit juices) so as to optimize their production cost. The developed technologies will be validated at the Tamarillo Kenya Limited (TAM) SME and in the Mukurweini Food Hub.

2. Objectives and description of the innovation

The objectives of the research at the University of Nairobi involves optimization of tree tomato juice extraction process and fortification of other products with the extracted fruit pulp.

Description of the innovation: an optimised process for pulping of tree tomato fruits will be developed. A therapeutic fruit juice incorporating tree tomato pulp will be developed.

2.1 Procedure and required actions

2.1.1 Optimization of the juice extraction process

Only good quality mature tree tomato fruits should be harvested. The quality of tree tomato fruits is important as it determines the quality of the processed pulp as well as that of its products. For the common red tomato fruit variety, immature fruits are green in colour. Partially red fruits with green and yellow portions on the surface are not yet ready for harvesting. Only those fruits that are completely red or have at least 97% of their surface red in colour should be harvested. The fruits are harvested by gently twisting and pulling to ensure that each fruit has its stalk still attached to it.

The harvested fruits should be handled in a hygienic way. The fruits should be stored until they ripen. Washing and rinsing with chlorinated water will be followed by cutting off the tops and tails. The fruits should then be pulped using a screw press after blanching with concurrent removal of skin and seeds that cannot pass through the screen.

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The yield and physicochemical properties of tree tomato pulp produced by different pulping methods will be obtained for the two tree tomato varieties. The following parameters will be determined:

- Pulp yield
- Pulp colour
- Pulp texture
- Pulp proximate composition
- Beta carotene
- Vitamin C
- Polyphenols
- Antioxidant activity

2.1.2 Development of a therapeutic fruit juice incorporating tree tomato pulp

For the production of the therapeutic juice, the tree tomato pulp is appropriately blended with other ingredients to ensure optimum physicochemical characteristics are obtained. The juice is pasteurised at 90 ^{0}C for 30 seconds. Use the hot-fill method to fill the product in suitable well labelled bottles before sealing and cooling.

2.2 Expected results

The expected results are the following:

(i) A fruit juice incorporating tree tomato pulp;
(ii) Chemical properties of the fruit juice:
  - Proximate composition;
  - Beta-carotene;
  - Vitamin C;
  - Mineral content;
  - Phenolic compounds content;
  - Antioxidant activity.

(iii) Sensory quality of the fruit juice
(iv) Storage stability of the packaged juice.
(v) The efficacy of the juice in stabilizing the blood sugar levels of pre-diabetic study participants in Mukurweini Food Hub

3. Risks and mitigation measures

The major risk is availability of the tree tomato fruit as it is seasonal. The mitigation measure is to intensify the activities when the fruit is in season.

4. Technology and production key performance indicators

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- Fruit pulp yield;
- Physicochemical properties of the fruit pulp including nutrients, antioxidants and colour;
- Physicochemical properties of the fruit juice including nutrients, antioxidants and colour;
- Microbiological quality of the fruit juice;
- Sensory quality of tamarillo fruit juice;
- Efficacy of the tamarillo fruit juice on pre-diabetic and diabetic participants;
- Technological acceptance of the innovative tamarillo juice technology; and
- Profitability of investing in a tamarillo juice production business.

5. Work plan

Activity No.	Activity	YEAR 1				YEAR 2				Comment (If any)
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
1	Optimization of tree tomato pulping									
2	Development of therapeutic tree tomato juice									Includes efficacy testing on pre-diabetic participants
3	Validation activities									SMEs and Mukurweini food hub community

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Subtask 4.5.3: Extrusion and baking

Leader: MAK
Participants: SUA, ISACM, NARO, UNIBO AND SME partners

1. Introduction

Extrusion and baking are food processing methods mainly used to produce pre-cooked foods that are easy to prepare or ready to eat. Hot extrusion entails use of high temperature and high-pressure treatment for a short time and is typically applied to flours. The pellets resulting from the hot extrusion process may be flavored to produce snacks or they may be milled to make flour, which is suitable for complementary feeding. Compared to raw flour, extruded flours give gruels with higher nutritional density, nutrient digestibility and bioavailability. Cold extrusion differs from hot extrusion as no heat is applied during the process. Cold extrusion is used to shape dough into cylindrical or flat shapes, which are then fried and/or dried to produce noodles. Baking, on the other hand is a widely used processing method, applicable at both domestic and commercial level, to make a variety of products, including bread, cakes, cookies, among others.

The main ingredients typically used in extrusion and baking are starchy staples, such as wheat and maize, which are generally low in proteins and micronutrients. Most extruded and baked products are therefore low in nutritional value. By blending starchy staples with more nutritious ingredients, it is possible to produce nutrient enhanced food products. The physico-chemical properties as well as the acceptability of such nutritionally enhanced products vary with the formulations and the processing conditions used. Studies are therefore needed before any formulations can be promoted among food operators. Technology development activities under this sub-task are largely aimed at developing formulations based on locally available ingredients and processing conditions that can be locally used for the production of acceptable nutrient enhanced baked and extruded food products.

The overall objective is to process different locally available foods into novel convenient nutrient rich products.

Specific objectives are to:

i. Produce and pilot nutrient dense flours that have potential to address nutritional gaps
ii. Produce and pilot nutrient dense snacks that have potential to substitute low nutritional value snacks
iii. Produce and pilot nutrient dense noodles from locally produced foods
iv. Determine the nutritional and physico-chemical properties of developed food products

This sub-task sought to utilise locally produced novel nutrient rich ingredients in the production of widely consumed food products and the promotion of the products among local food operators and consumers.

2. Description of small-scale tests and results

2.1 Operative procedures and products

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2.1.1 General indications to be considered in production

The general procedure followed for the different products is summarised in Figure 1.

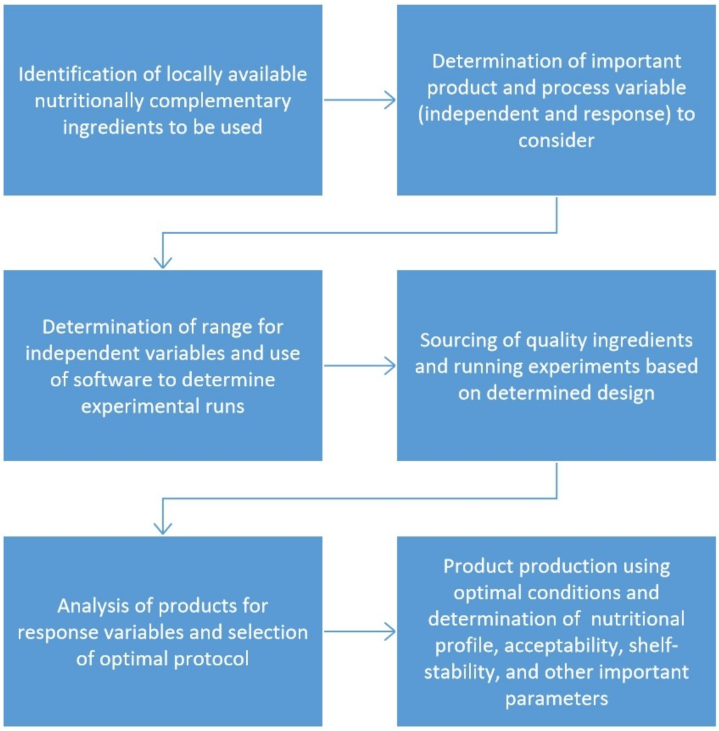

Figure 1. General procedure used in developing protocols for extruded and baked products

2.1.2 Specific procedures for products

Flours with orange fleshed sweet potatoes as main ingredient

Composite flours were formulated from maize, orange fleshed sweet potatoes, biofortified beans and grain amaranth using 20 runs generated using Central Composite Design of the Expert Design Version 13 Software, based on the limits specified in Table 1 below.

Table 1. Experimental design for formulations of composite flours with orange fleshed sweet potatoes, maize, biofortified beans and grain amaranth

	X_1	X_0	X_{-1}
Maize	30	10	0
Orange fleshed sweet potatoes	70	50	20
Biofortified beans	40	30	20
Grain amaranth	30	20	10

Five kg of each of composite flours made using the 20 formulations were extruded using DP 70-III Twin Screw Extruder (Jinan Eagle Machine Co. Ltd, Jinan, China) at operating temperatures of 60, 130 and 150 ℃, respectively for zones I, II and III and frequency setting of 47, while 5 kg were kept raw.

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Flour with cereals as main components

Locally grown cereals (maize and millet), legumes (bio-fortified common beans and soya beans), and oil seeds (sesame seeds) were used as the main ingredients for the formulation of extruded composite flour. Soybean and sesame seed were used to increase the protein and fat contents, respectively. Maize, millet, soybeans, and sesame seeds were purchased at the local market in Morogoro, Tanzania while bio-fortified common beans were obtained from one of the FoodLAND bean projects at Mvomero Food Hubs. These materials provided optimum proportions of ingredients according to the desired amino acid profile requirements. Proportions of food ingredients were obtained through a computer program by blending essential amino acid compositions similar to those recommended by FAO, WHO, and UNICEF for children. The goal is to create composite flour with 360 energy (kcal), 65 amino acid score (AAS), 15 g protein, and protein energy of 10 - 20%. The proportion of the four formulations selected for study is shown in Table 2. Except for sugar, all raw materials were cleaned and washed to remove any dust, stones, or damaged seeds before drying for 12 hours at 60 °C before milling into flour.

Table 2. Raw materials and ingredients used for formulations of composite flour

Ingredients/ formulations	**1**	**2**	**3**	**4**
Maize (%)	60	50	52	53
Millet (%)	10	15	10	5
Soybean (%)	10	10	10	7
Common beans (%)	15	20	25	30
Sesame seeds (%)	5	5	3	5
Sugar for taste	3	3	3	3

Extruded composite flours were developed by using a twin screw extruder at a barrel temperature of 94–97 °C for zone 1 and 102-110 °C for zone 2 at a screw speed of 300 rpm with a feed moisture content of 13–15% (wb). Before milling into powder, the extruded material was allowed to cool for 12 hours at room temperature.

Noodles from orange fleshed sweet potatoes and other ingredients

The procedure for production of noodles of noodles from OFSP and other ingredients is given in Figure 2.

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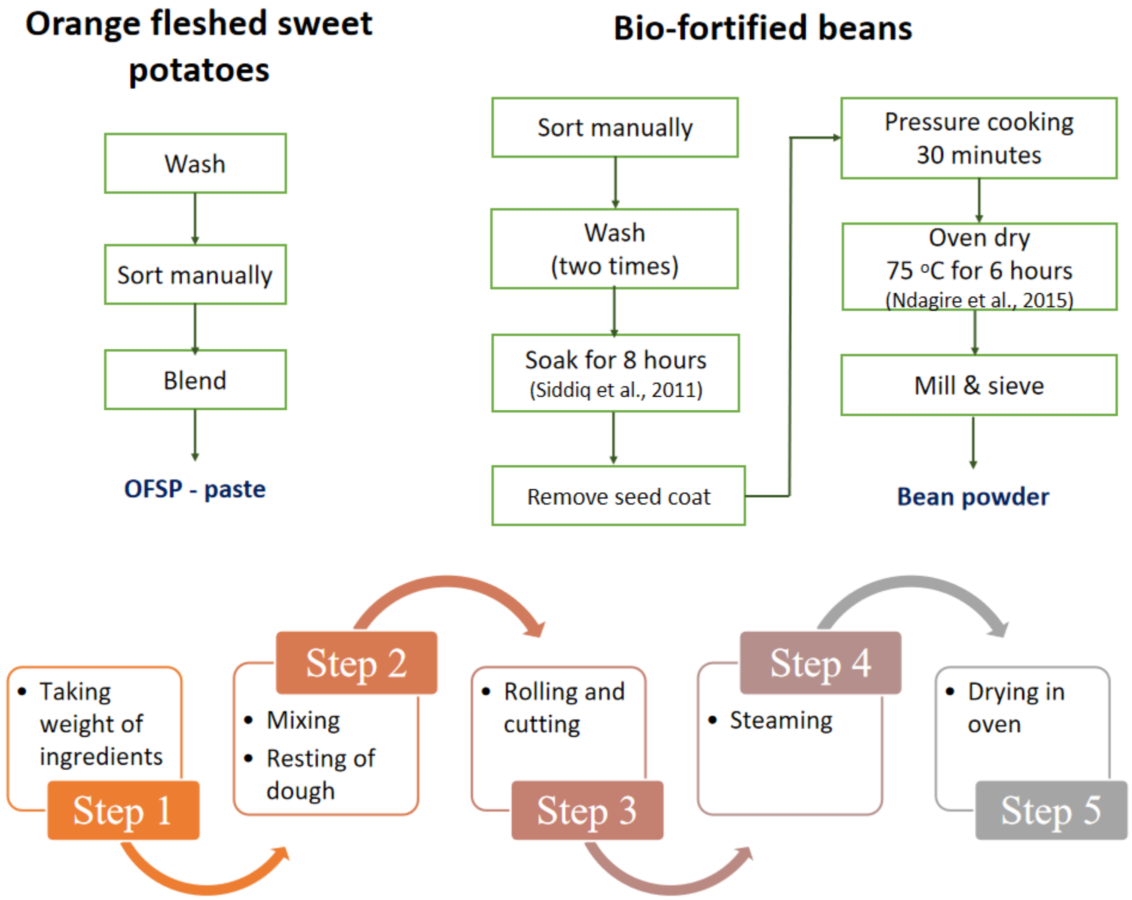

Figure 2: Procedure followed in production of noodles from orange fleshed sweet potatoes and other ingredients

Mixture design of Design Expert was used to obtain formulations and processing conditions for production of noodles from wheat flour, orange fleshed sweet potatoes and bio-fortified beans. The processing conditions considered in developing experimental runs were noodle thickness, drying temperature and time. A total of 68 experimental runs were generated (Table 3) and used for production of samples.

Table 1: Experimental runs generated for optimization of production of enriched noodles

Run	Wheat (g)	OFSP (g)	Beans (g)	Thickness (mm)	Temperature (°C)	Time (min)
1	75.00	20.00	7.50	3.00	90.00	105.00
2	60.00	15.00	5.00	4.00	89.50	60.00
3	60.00	18.50	10.00	2.00	100.00	150.00
4	90.00	15.00	6.98	2.00	91.10	150.00
5	90.00	15.00	5.00	4.00	80.00	101.85
6	72.00	22.30	10.00	4.00	86.07	127.95

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Run	Wheat (g)	OFSP (g)	Beans (g)	Thickness (mm)	Temperature (ºC)	Time (min)
7	67.50	17.75	5.00	2.00	80.00	69.00
8	60.00	25.00	10.00	3.00	80.00	100.50
9	60.00	15.00	5.00	2.00	100.00	109.05
10	90.00	15.00	10.00	4.00	90.20	78.00
11	80.85	25.00	7.33	4.00	80.00	60.00
12	90.00	25.00	8.38	4.00	80.00	150.00
13	90.00	15.00	10.00	2.00	100.00	101.40
14	90.00	19.85	5.00	3.00	88.50	150.00
15	90.00	19.85	5.00	3.00	88.50	150.00
16	60.00	15.00	7.25	3.00	80.00	103.65
17	72.15	15.00	5.00	2.00	80.00	150.00
18	60.00	15.00	9.88	4.00	89.50	150.00
19	90.00	25.00	10.00	3.00	91.40	60.00
20	60.00	25.00	5.00	3.00	80.00	60.00
21	75.75	20.80	5.00	2.00	95.00	60.00
22	75.00	20.00	7.50	3.00	90.00	105.00
23	75.00	20.00	7.50	3.00	90.00	105.00
24	75.00	20.00	7.50	3.00	90.00	105.00
25	75.92	25.00	10.00	2.00	92.00	150.00
26	60.00	15.00	10.00	2.00	85.20	60.00
27	75.00	20.00	7.50	3.00	90.00	105.00
28	90.00	20.65	5.13	3.00	84.60	60.00
29	90.00	25.00	10.00	3.00	91.40	60.00
30	69.90	19.20	10.00	4.00	80.00	60.00
31	90.00	25.00	5.00	2.00	80.00	105.00
32	75.75	15.00	5.75	4.00	100.00	150.00
33	75.00	20.00	7.50	3.00	90.00	105.00
34	75.00	20.00	7.50	3.00	90.00	105.00
35	90.00	24.00	7.85	2.00	100.00	60.00
36	79.50	21.25	10.00	4.00	100.00	71.17
37	76.37	15.02	9.55	4.00	100.00	121.00
38	75.00	20.00	7.50	3.00	90.00	105.00
39	60.00	25.00	8.13	2.00	100.00	60.00
40	90.00	20.75	10.00	2.00	80.00	100.50
41	90.00	18.40	5.00	2.00	100.00	110.85
42	81.90	15.00	10.00	3.00	80.00	150.00
43	60.00	15.00	7.25	3.00	80.00	103.65
44	90.00	25.00	5.00	4.00	100.00	64.05

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Run	Wheat (g)	OFSP (g)	Beans (g)	Thickness (mm)	Temperature (ºC)	Time (min)
45	90.00	21.05	10.00	4.00	100.00	150.00
46	60.00	25.00	7.32	2.00	80.00	150.00
47	89.25	25.00	7.79	4.00	93.50	109.02
48	72.15	15.00	10.00	3.00	100.00	60.00
49	60.00	22.00	7.15	4.00	84.00	88.75
50	86.55	17.03	9.68	3.00	80.00	60.00
51	75.92	25.00	10.00	2.00	92.00	150.00
52	60.00	18.75	5.00	4.00	95.90	115.80
53	60.00	19.50	7.38	4.00	100.00	60.00
54	74.70	25.00	6.50	3.00	100.00	78.90
55	60.00	25.00	5.00	3.00	100.00	150.00
56	90.00	25.00	6.75	2.00	100.00	140.55
57	90.00	15.00	5.00	3.00	100.00	60.00
58	60.00	23.05	8.54	3.00	93.10	150.00
59	75.00	20.00	7.50	3.00	90.00	105.00
60	81.90	15.00	10.00	3.00	80.00	150.00
61	90.00	20.75	10.00	2.00	80.00	100.50
62	90.00	15.00	10.00	4.00	90.20	78.00
63	75.75	15.00	5.75	4.00	100.00	150.00
64	72.00	25.00	5.00	4.00	90.60	118.50
65	60.00	20.29	5.00	4.00	80.00	150.00
66	60.00	15.00	10.00	2.00	85.20	60.00
67	60.00	25.00	10.00	4.00	100.00	106.80
68	90.00	15.00	6.88	2.00	80.00	60.00

The ingredients in amounts specified in the experimental runs were mixed using a mixer (Sokany mini wonder chopper SK-7005) and kneaded by hand to produce a dough, which was shaped using a pasta maker (Marcato Design Atlas 150 *Pasta Machine). Thickness was set as per the* experimental runs generated. The noodles were steamed for 10 minutes and then dried in a hot air oven (Gallenkamp, UK) at the set temperature and time as *per the* experimental runs generated. They were further air cooled and packaged in airtight zip-lock bags prior to analyses.

Extruded fish bone-maize snack

Fish powder was prepared from the bones of tilapia and catfish (Fig. 3). Maize grits were procured from a dealer in Kawanda, Wakiso district, Uganda. Maize grits were ground to pass through 200 µm sieve using laboratory mill. Several preliminary trials were made to select the mixing ratio of fish flour incorporation into maize flour. The fish bone flour was mixed with the maize flour in the ratio of 1:2 in a ribbon blender for 15 min to ensure uniform mixing. Salt and dried spices of choice (in powder form) were added at 2% into the mixture and again blended for 10 min. The mixture was introduced into the hopper of a single screw extruder (Sejin Machinery Co., Seoul, South Korea) and extruded at 150 - 160 °C, screw speed - 1450 rpm and cutting speed 350 rpm.

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Figure 3. Preparation of extruded fish bone-maize snack

The extruded products (moisture content 17%) were cooled for 5 minutes and packaged immediately in a lined polypropylene bag to prevent moisture absorption from the atmosphere.

Bean sauce

Biofortied beans (NARO Bean 1) were sifted and sorted on a wire mesh to remove chuff, broken and shrivelled grain. The sorted beans were washed thrice with potable tap water and dried on wire mesh racks in a solar tent drier, until they attained a moisture content of 11-12%. The dry beans were milled using a commercial mill (Model YZMF, Yize, Shuliy Henan, China) with a 1.5 mm sieve and the flour was stored in plastic bags at room temperature (23–27 ℃).

The bean flour was extruded. Briefly, the bean flour was conditioned to a moisture content of 20% and thoroughly mixed using a mixer for 15 min. The conditioned flour was then extruded using a DP70-III double screw inflating food machine (Jinan Eagle Machine Co. Ltd., Jinan, China). The extruder conditions were: feeding frequency of 30 Hz, cutting frequency of 50 Hz, and barrel temperatures of 60°C, 130°C, and 150°C in first, second, and third zones, respectively. After extrusion, the samples were cooled to room temperature under natural convection conditions. The samples were then milled into flour using a 30 B-C milling machine (Changzhou Erbang Drying Equipment Co. Ltd., China), packed in 225 mm * 40 mic BOPP bags, a label was attached and the product was stored at ambient conditions until further use.

Developing a recipe for preparation of bean sauce using the extruded bean flour

Bean sauce was prepared using a recipe previously developed by Nutreal Limited. Briefly: 1 finely chopped large onion was sautéed in 2 tablespoons of cooking oil; 2 finely chopped tomatoes were

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added and cooked; 2 heaped table spoons of bean flour were added and stirred; 500 ml of hot water was added slowly while stirring; salt and seasonings were added to taste and the sauce was simmered for 10 minutes before serving.

Composite flour with legumes as main component

Design Expert version 13 software was used to formulate 14 combinations based on flour from wheat, peas, chickpea and Faba beans, with legumes constituting at least 80%. The formulations will be evaluated for suitability for extrusion cooking and baking as well as for up-scaling in the Chebika/Enfidha Food Hub.

Baked products

Cookies made from wheat and legume-based composite flours

The development of cookies was based on different composite flour formulations using wheat (90, 85 and 80%) and untreated microwave heated and germinated legumes (faba bean, pea and chickpea) added at mixture levels of 10, 15 and 20%. The supplemented ingredients were eggs, vegetable fat, sugar, milk powder, salt and baking powder. Different cookies were subjected to nutritional and physical and sensory analysis. Based on the obtained results and the legumes price the cookies made by untreated or germinated faba bean at 20% was selected for the validation. Validated product was subjected to the same characterization analysis (Figure 4).

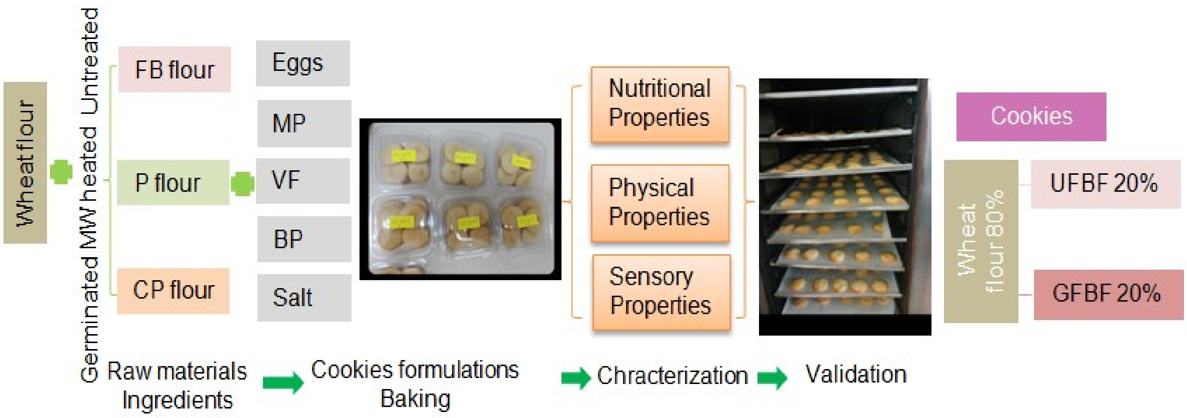

Figure 4. Summary of the R&I activities: from testing to validating of snacks (cookies based on wheat legumes composite flour), FB: faba bean; P: Pea; CP: chickpea; MP: milk powder; VF: vegetable fat; BP: baking powder; UFBF: untreated faba bean flour and GFBF: germinated faba bean flour

Nutrient enriched baked snacks containing orange fleshed sweet potatoes, grain amaranth and biofortified beans

Baked doughnuts (commonly referred to as *daddies* in Uganda) were made using 40% non-instant flour constituted of orange fleshed sweet potatoes (OFSP), grain amaranth and biofortied beans

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flour and 60% wheat. The composite flour used was made from an RSM optimised formulation and consisted of 37.8% OFSP, 32.2% biofortified beans and 30% grain amaranth. Properties of flour used and the optimisation process are reported in D 5.11. Other ingredients used were wheat flour, sugar, eggs and butter. For every 100 kg of flour, 25 kg of sugar, 25 kg of margarine, 10 eggs, 500 g of baking flour were used. Vanilla essence (0.2%), carboxymethly cellulose (CMC) (0.1%), and water (8%) were also used. The ingredients were kneaded into a dough. The dough was then shaped into daddies (cuboid shape) form (5.0 x 5.0 cm) and baked in an electric oven at 150°C for 55 minutes. *Daddies* were removed from the oven and allowed to cool at ambient temperature for about 10 minutes, packed in polyethylene bags for subsequent analyses. The doughnuts were subjected to proximate composition analysis and sensory evaluation.

2.2 Products analysis and results

2.2.1 Analysis of products

Composite flour based on orange fleshed sweet potatoes

Raw and extruded samples were analysed for protein content (AOAC, 2016), beta carotene (Tiony & Irene, 2021), zinc and iron (Paul et al., 2016) as well as paste final viscosity (RVA 4500, Perten Instruments, Hägersten, Sweden).

Analysis of flours based on cereals

The raw materials and the developed composite flours were analyzed for proximate analysis (moisture, crude protein, crude fibers, ash, and carbohydrate), total phenol and for physical properties of the products such as bulk density (BD), water absorption index (WAI), water solubility index (WSI), oil absorption and angle of repose.

Noodles

Noodles produced using the different experimental runs were analysed for moisture, protein, dietary fibre (AOAC, 2016), carotenoids (Tiony & Irene, 2021), hardness (using TA XT2 Texture Analyser, Stable Micro Systems, Godalming, England), and for iron, and zinc content (Paul et al., 2016). The noodles were also analysed for sensory acceptance and ooking properties.

Extruded fish bone-maize snack

Sensory evaluation was carried out according to Santana et al. (2015) to determine product acceptability of the fish based products.

Cookies made from wheat and legume-based composite flours

Developed cookies were analysed for proximate composition, phenolics content and intrumental texture determination using standard methods.

2.2.2 Properties of products

Composite flour based on orange fleshed sweet potatoes

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The properties of the raw and extruded flours made from the different formulations are provided in Table 4 below.

Table 4. Proximate composition of optimal formulations of orange-fleshed sweet potatoes containing flours compared to a commercial composite flour

Sample	Moisture	Crude protein	Dietary fibre	Ash	Crude fat	Carbohydrates
COMM	7.72^{b} ±0.15	15.45^{c} ±0.02	0.46^{e}±0.08	1.39^{c}±0.03	5.65^{a} ±0.21	69.79 ^{ab}±0.65
RF1	8.15^{a} ±0.12	18.16^{a} ±0.81	4.04^{a}±0.05	3.61^{a}±0.06	4.65^{ab} ±0.07	65.43^{c}±1.43
RF2	7.84^{ab} ±0.01	17.55^{ab} ±0.50	3.39^{b} ±0.16	2.95^{b} ±0.07	2.35^{c} ±0.21	69.31^{b} ±0.41
EF1	5.84^{d} ±0.00	16.39^{bc} ±0.03	2.15^{c} ±0.08	3.81^{a} ±0.22	4.10^{b} ±0.49	69.86^{ab} ±0.54
EF2	6.33^{c} ±0.19	16.13^{c} ±0.43	1.45^{d} ±0.19	3.16^{b} ±0.19	2.30^{c} ±0.28	72.08^{a} ±2.65

Results are presented as means ± standard deviation. Means in the same columns with different superscripts are significantly (p<0.05) different. COMM: commercial composite flour, RF1 and RF2 are raw composite formulations, EF1 and EF2 are extruded composite formulations

The formulated flours also contained enhanced levels of beta-carotene, zinc and iron. The extruded flours exhibited markedly lower viscosity compared to raw flours. Detailed results for the physico-chemical characterisation of the developed flours are reported in D5.16.

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Flours based on cereals

Table 5. Proximate composition of raw materials and extruded composite flour based on cereals

S/N	Sample number	Moisture content (%)	Crude protein (%)	Crude fiber (%)	Crude fat (%)	Ash content (%)
1	Soybean flour	6.45	39.45	8.88	7.25	4.73
2	Maize flour	6.91	11.63	2.05	10.96	1.38
3	Biofortified common bean flour	8.99	18.03	5.59	6.4	3.26
4	Sesame seed flour	9.67	20.6	19.74	23.99	4
5	Millet flour	12.87	5.6	2.74	3.68	2.42
6	Extruded composite flour	3.07	12.9	0.46	4.48	2.22

Table 6. Physico-chemical properties of raw materials and extruded composite flour

S/N	Sample number	Water absorption index 'WAI'	Water solubility index 'WSI'	Oil absorption index 'OAI'	Bulk density, g/cm3	Angle of Repose
1	Soybean flour	4.84	84	0.65	0.404	69.25
2	Maize flour	4.77	17.5	0.75	0.558	72.01
3	Biofortified common bean flour	4.87	42.5	1.24	0.57	71.45
4	Sesame seed flour	4.7	19	2.18	0.436	62.15
5	Millet flour	4.46	6	1.94	0.564	67.55
6	Extruded composite flour	7.41	38	1.36	0.506	65.75

In addition, mineral contents of the raw materials and extruded composite flour were also analyzed as shown in Table 7.

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Table 7. Minerals, Vitamin A and Phenols content of raw materials and composite flour

				Minerals contents mg/kg, except K is in %								
S/No		Vitamin A (µg/100g)	Total phenol (mg/100g)	Cu	Zn	Fe	Mn	Ca	Mg	K %	Na
1	Soybean flour	391.7	2.92	9.65	57.02	75.48	40.92	29.49	254.75	0.54	78.25
2	Maize flour	438.36	1.47	2.26	39.08	26.38	8.4	0.86	164.46	0.12	71.88
3	Biofortified common bean flour	113.56	0.96	7.35	48.42	66.1	10.3	16.92	385.19	1.11	75.92
4	Sesame seed flour	258.06	1.34	14.15	70.51	49.49	30.01	102.09	533.1	0.74	43.43
5	Millet flour	60.66	2.31	7.03	35.06	52.41	3.48	41.36	380.18	0.16	116.37
6	Extruded composite flour	87.3	1.31	4.51	42.59	198.51	27.29	11.88	302.27	0.36	123.25

Noodles

The composition of noodles obtained using optimal formulation and process are provided in Table 8 below.

Table 8: Proximate analysis for the orange fleshed sweet potato and biofortified beans containing noodles

Sample	% Composition						
	Moisture	**Ash**	**Dietary fibre**	**Fat**	**Protein**	**Carbohydrates***	**β-carotene (mg/100g)**
Control	$5.90^{a} \pm 0.11$	$0.5^{a} \pm 0.1$	$0.52^{a} \pm 0.010$	$0.49^{a} \pm 0.02$	$14.2^{a} \pm 1.42$	69.85	$0.04^{a} \pm 0.23^{1}$
Nutrient enhanced noodles	$5.98^{a} \pm 0.07$	$2.1^{b} \pm 0.1$	$11.77^{b} \pm 0.67$	$0.61^{a} \pm 0.08$	$35.06^{b} \pm 0.39$	44.48	$0.54^{b} \pm 0.01^{1}$

*Values are means ± standard deviation of at least three determinations (n=3). Means in a column with different superscript are statistically different (p ≤ 0.05). *Derived by difference.*

Table 9. Cooking properties and colour of wheat noodles (control) and composite noodles containing orange fleshed sweet potatoes and biofortified beans

Property	Developed composite noodles	Control
Cooking time (s)	$1083.80^{b} \pm 8.82$	$915.20^{a} \pm 4.45$
Cooking loss (%)	$6.22^{a} \pm 0.09$	$8.98^{b} \pm 0.34$
Cooking yield (%)	$219.88^{b} \pm 1.44$	$184.73^{a} \pm 4.00$
Colour		

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L*	39.25ᵃ±1.05	46.81ᵇ ± 0.30
a*	4.50ᵇ±0.40	2.30ᵃ ± 0.21
b*	20.85ᵃ ± 1.36	19.03ᵃ ± 0.90

Table 10. Sensory properties of wheat noodles (control) and composite noodles containing orange fleshed sweet potatoes and biofortified beans

Property	Developed composite noodles	Control
Appearance	$7.44^{a} \pm 1.18$	$7.7^{a} \pm 0.99$
Colour	$7.6^{a} \pm 1.14$	$7.7^{a} \pm 1.18$
Aroma	$7.9^{a} \pm 1.10$	$7.8^{a} \pm 1.17$
Taste	$7.5^{a} \pm 1.27$	$7.6^{a} \pm 1.17$
Mouthfeel	$7.6^{a} \pm 1.09$	$7.5^{a} \pm 1.22$
Aftertaste	$7.6^{a} \pm 1.12$	$7.6^{a} \pm 1.11$
Overall acceptability	$7.8^{a} \pm 1.06$	$8.0^{a} \pm 0.95$

Values are means ± standard deviation of at least three determinations (n=50). Scores for each sensory attribute based on a 9-point hedonic scale: 1=disliked extremely, 2=disliked very much, 3=disliked moderately, 4=disliked slightly, 5=neither liked nor disliked, 6=liked slightly, 7=liked moderately, 8=liked very much, 9=liked extremely

Based on sensory evaluation scores, the developed noodles were highly acceptable (Table 10). This shows that the product is likely to be accepted by the market, if produced at commercial scale.

Bean sauce

High sensory acceptability of the bean sauce prepared using the bean flour was established among a key target market segment. Overall the bean sauce was liked very much and moderately by the majority of respondents resulting in a combined like score of 85.8%. Only 9.2% neither liked nor disliked the product and only 5% indicated that they did not like the product. The color of bean sauce was liked very much and moderately by a combined 94% the respondents. Only 5% of the respondents were undecided and only 1% said that they did not like the colour. Similarly, the aroma of bean sauce was liked very much and moderately by the respondents resulting in a combined like score of 91.1%. Only 5% of the respondents were undecided and only 4% indicated that they did not like the aroma of the product. The thickness of the bean sauce was liked by all the respondents. The taste of bean sauce was liked very much and moderately by the respondents resulting in a combined like score of 87.5%. Only 6.6% were undecided and only 6% indicated that they did not like the taste. The aftertaste of bean sauce was also liked very much and moderately by the respondents resulting in a combined like score of 90.7%. Only 5.6% were undecided and only 3.7% indicated that they did not like the aftertaste of the sauce.

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Fish bone-maize snack

Extruded fish bone - maize snack composition was found to consist average of 11.9% crude protein, 5.5% crude fat and 5.1% ash. The snack was generally acceptable to sensory panelists, with scores for different sensory properties (n=35) ranging from 4.7 to 6.8 on a 9-point hedonic scale.

Cookies made from wheat and legume-based composite flours

The results demonstrated that the developed cookies exhibited acceptable sensory properties and contained significantly higher protein and phenolics compared to cookies not supplemented with legumes. The developed cookies were therefore nutritionally superior to commercially available cookies and have potential to contribute to improved nutrition.

Nutrient enriched baked snacks containing orange fleshed sweet potatoes, grain amaranth and biofortified beans

Snacks produced contained relatively high levels of protein and fibre (Table 11) compared to snacks made from only refined wheat. This can be attributed to the relatively high nutritional value of the composite flour used to replace wheat. The snack is generally high in fat, which makes it a high energy product, that's suitable for very active individuals such as school-age children. These snacks (*daddies*) are commonly consumed by children in boarding schools. These are unlikely to have a problem with excessive energy intake. The high energy content of the snack is therefore not likely to lead to overweight and obesity.

The snacks' sensory scores (Table 12) for all attributes were relatively high (≥7.8 on a 9 point scale). This shows that the product was well accepted by panelists. This is indicative of high potential for market acceptability.

Table 11. Nutritional composition of baked snacks with wheat partially substituted with orange-fleshed based composite flour

Water	Protein	Ash	Fibre	Fat	Carbohydrates	β carotene	Iron	Zinc
3.81+0.11	18.72±0.38	1.88±0.05	1.77±0.06	20.23±0.16	52.59±1.68	0.548±0.056	0.892±0.028	0.493±0.024

Table 12 Sensory evaluation of baked snacks with wheat partially substituted with orange-fleshed based composite flour

Appearance	*Taste*	*Overall acceptability*

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7.8±1.4	*7.9*±1.3	*8.4*±1.1

n= 35

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