**Original Research Article**

**Production and characterisation of potato (*Solanum tuberosum)* chips produced with Moringa leaves powder and soybean flour**

**ABSTRACT**

**Aims :** Food insecurity and malnutrition are part of the major problems in developing countries and there is a need to develop enriched foods to tackle these problems. This work aimed at producing and characterising enriched potato chips using moringa powder and soybean flour.

**Methodology :** Samples of potato chips with various concentrations of moringa powder and/or soybean flour were prepared and their nutritional parameters, energy, antioxidant components and sensory properties investigated. .

**Results**: Fiber and ash contents increased markedly with addition of moringa and combination of soybean and moringa as compared to the control sample. The addition of either soybean and/or moringa increased the protein and fat contents with the highest effect observed with 15% soybean and 15%moringa ;15%soybean. As compared to other samples, soybean-enriched potato chips samples displayed higher amounts of total calories. Globally, supplementation with soybean and/or moringa decreased the moisture content of the potato chips (from 5.67±0. 22 % in 100 % potato chips to 2.16±0.01 % in potato chips containing 15% moringa and 10% soybean) . The addition of moringa powder especially from 15% and moringa in combination with soybean significantly increased the β-carotene content of the potato chips (from 0.01±0.01mg/100g in 100 % potato chips to 0.58 ±0.03mg/100g in sample containg 15% moringa and 15% soybean). Enriched potatoes were highly accepted except for those containing moringa. In conclusion, moringa and/or soybean-enriched potato chips display distinct nutritional, antioxidant, and sensory properties.

**Conclusion**: Combined moringa and soybean-based potato chips demonstrated high nutrient and antioxidant contents that support their potential consideration in the prevention or management of related health affections within our communities.

**Keywords:** *Food enrichment, Potato chips, Moringa, Physico-chemical properties, Soybean*.

**1. INTRODUCTION**

Food security remains a major concern in most African countries with high population growth rates, high levels of post-harvest losses, and limited transformation of agricultural products to feed an ever-growing population. Given that most crops are seasonal, there is a need for the transformation of crops into improved value-added products with increased stability and shelf life, to meet an all-year-round demand of non-producing areas (Mukasa et al. 2017; Stathers et al. 2020; Wudil et al. 2022).

Potato scientifically known as *Solanum tuberosum* is an important worldwide crop that ranks fourth as the world's largest food crop after maize (corn), wheat, and rice. *S. tuberosum* can be processed into many products with different nutritional attributes and implications ranging from undernutrition, and disease occurrence to issues of overnutrition which include obesity, diabetes, heart disease as well as food insecurity. It is one of the leading food crops thanks to its unusually wide adaptability to very different conditions of soil and climate which fosters its cultivation throughout the continents (Furrer et al. 2018). In Cameroon, the production of *S. tuberosum* has been very steady since 1997 with a global annual production reaching 350,000 tons in 2015 (Tambi and Bobuin 2023). Potato contains compounds and nutrients including phenolic acids, anthocyanin, flavonoids, vitamin B6, vitamin B3, pantothenic acid, potassium, manganese, phosphorous; copper, and fibres (Anjum et al*.* 2018). It is easily processed into potato products such as crisps, flakes, canned and mashed potatoes, ready meals, and fried chips (Naziri et al. 2024).

Moringa oleifera commonly known as Moringa is an edible tree found worldwide that originated from the Himalayas but is also found in the dry tropics, and is increasingly being used for nutritional supplementation. M. oleifera leaves are rich in nutrients such as provitamin A, vitamin C, calcium, potassium, iron, and protein (Abbas et al. 2018). It is used for the management of diseases including respiratory illnesses, ear and dental infections, hypertension, diabetes, and cancer treatment. In fact, it has demonstrated potential health benefits which include anti-oxidant, anti-diabetic, anti-microbial, anti-inflammatory, and anti-cholesterol properties (Anwar et al*.* 2007; Paikra et al. 2017). On the other hand, *Gylcine max* commonly called soybean is a food with high nutritional value and it is probably the world’s most valuable crop and most used item in livestock feed globally. Soybean is a source of dietary protein for millions of people and it is used in the manufacture of many items. Owing to this high nutritional value, it is used as a nutritional supplement for pregnant women, lactating mothers, and children (Fabiyi 2009). Moringa and soybean thanks to their nutritional and health benefits are therefore suitable as enhancers for the formulation of fortified or enriched foods essential in the fight against nutrient-related diseases.

Potato contributes to national food security (Woin et al. 2019). Local processing of potatoes can greatly contribute to combating urban malnutrition and food insecurity in Cameroon (Nossi et al.2020). Despite the ability of potatoes to contribute to national food security, it however does not meet the Recommended Daily Intake of micronutrients notably iron levels in humans. On the other hand, moringa being an underutilized crop in some areas (Melo et al*.* 2013) yet containing an exceptional concentration of nutrients (Abbas et al. 2018) can be incorporated into food to address nutrient deficiencies (Chan et al. 2021; Trigo et al. 2023). Also, soybeans being a rich source of high-quality protein and fat, and a good source of energy can therefore be used to address protein-calorie malnutrition (Fabiyi 2009). This study was therefore designed to produce and characterise potato chips enriched with moringa and/or soybean as a contribution to the fight against nutrient-related diseases.

### 2. MATERIALS AND METHODS

**2.1.** **Vegetal material and other ingredients**

Potato (*Solanum tuberosum)* and soybeans (*Gylcine max)* were purchased from market sellers at the Bamenda Food Market (North West Region of Cameroon) in March 2024. Moringa (Moringa oleifera) leaves were harvested in Bamenda in March 2024, dried at room temperature, and grinded into fine powder using a household blender and packaged in plastic bags. Soybeans were grilled for 5 minutes then milled using a household blender and stored in plastic bags. The plant materials were identified by Prof. Njouonkou Andre Ledoux, a botanist from the Faculty of Science of the University of Bamenda.

### 2.2. Enriched potato chips production

For the production of enriched potato chips, potatoes were trimmed, washed with potable water, peeled, and sliced into pieces of 6 to 8 mm thickness. The sliced potatoes were boiled (100oC) for 35 minutes and the excess water was removed. The potatoes were pounded to a uniform consistency product.

Then seven samples were produced as follows: sample A made up of 100% potato, sample B made up of potato with 10% soybean, sample C: potato with 15% soybean, sample D: potato with 10% moringa, sample E: potato with 15% moringa and 10% soybean, sample F: potato with 10% moringa and 10% soybean and sample G: potato with 15% moringa and 15% soybean.

Thereafter, the following ingredients: salt (1 g), sugar (2 g), milk powder (3 g), vegetable oil (3 mL), and cinnamon powder (0.2 g) were added and after thorough homogenization, 2 g of the mixture were toasted at 140°C for 3 minutes using a toasting machine (Russell Hobbs) to produce chips. The products were allowed to cool before packaging and storage at room temperature.

## 2.3. Nutritional characterization of the enriched potato chips

The protein, fiber and moisture contents of the enriched potato chips were determined using the Kjeldahl, gravimetric and drying methods, respectively as described by Saha et al. (2022). Lipid levels were quantified using the Soxlhet method while the ash content was assessed by burning of sample for hours at 550oC in a muffle furnace (Carpenter 2010). Carbohydrates content was obtained by difference calculation considering the other nutrients (ash, fats, proteins) as reported by Mezgebo et al. (2018).

### 2.4. Determination of mineral and antioxidant contents

Mineral analysis of potato chips consisted of determination of iron, zinc, potassium and calcium content. It was determined according to the methods described by Ogbemudia et al. (2017). The antioxidant components evaluated were total carotenoids and total phenolic compounds. The total carotenoids were obtained using the AOAC spectrophotometric method as described by Islam and Schweigert (2015) method while the total phenolic compounds were determined using the Folin–Ciocalteu method as reported by Soh et al. (2022).

## 2.5. Sensory evaluation

The sensory panel was made up of 40 untrained panelists both male and female within the age range of 18-50 years. Each judge was given a sensory evaluation sheet having a 9-point hedonic scale with 1 and 9 corresponding to the appreciation of dislike and like extremely respectively (Nain et al. 2019). Sensory attributes evaluated were: colour, taste, aroma, texture or mouthfeel, crispiness, and overall acceptability.

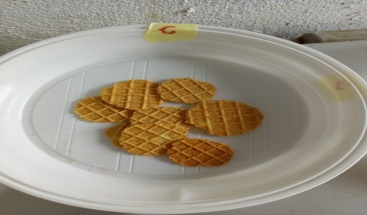
## 2.6. Statistical analysis

The data obtained were expressed as mean ± standard deviation and were subjected to the Analysis of Variance (ANOVA) followed by the Fischer Test for assessment of any difference among samples. All analyses were done using Statgraphics Plus Version 5.0 statistical package. Differences at the *P*<0.05 were considered significant.

**3. RESULTS**

## 3.1. Enriched potato chips and sensory attributes

The appearance of the potato chips produced using the incorporation of moringa leaf powder and/or soybean.



**A**

**B**

**C**

**D**

**E**

**F**

**G**

**Fig. 1. Different potato chips obtained after processing**

A: 100% potato, B: potato with 10% soybean, C: potato with 15% soybean, D: potato with 10% moringa, E: potato with 15% moringa and 10% soybean, F: potato with 10% moringa and 10% soybean, G: potato with 15% moringa and 15% soybean.

Globally potato chips enriched with 10 and 15% soybean flour as well as without enrichment showed the most appreciated colour, aroma, texture, crispiness, taste, and overall acceptability (Table 1). This signifies that moringa flour due to its content in better and dark ingredients could have influenced the appreciation of potato chips by the panelists.

**Table 1: Sensory properties of the processed potato products**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample** | **Colour** | **Aroma** | **Texture** | **Crispiness** | **Taste** | **Overall acceptability** |
| A | 7.7±0.73a | 6.95±1.43a | 7.55±1.57a | 7.45±1.23a | 7.7±0.92a | 7.5±1.24a |
| B | 8.0±0.92a | 7.15±1.46a | 7.8±0.01a | 7.55±1. 23a | 7.95±0.94a | 8. 25±0.72a |
| C | 8.35±1.18a | 7.85±1.03a | 7.35±1. 26a | 7.45±1.34a | 7.5±1.32a | 7.7±1.17a |
| D | 5.2±1.91bc | 5. 2±1.82b | 5.75±1.41b | 6.85±1.41a | 7.1±2.49b | 7.0±1.59ab |
| E | 5.4±1.79bc | 5. 2±1.61b | 5.4±1.78b | 5.45±1.50b | 4.85±2.08b | 4.9±1.48c |
| F | 5.85±1.72b | 5.1±1.74b | 5.5±1.73b | 4.35±1.73c | 4.65±2. 21b | 4.95±1.96c |
| G | 4.7±2.18c | 5.1±1.68b | 4.8±1.85b | 4.2±1.99c | 3.75±2.27b | 4.05±2.04c |

Mean ± SD, values within the same column with different superscript letters are significantly different from each other (*p<.05*)A: 100% potato, B: potato with 10% soybean, C: potato with 15% soybean, D: potato with 10% moringa, E: potato with 15% moringa and 10% soybean, F: potato with 10% moringa and 10% soybean, G: potato with 15% moringa and 15% soybean.

## 3.2. Nutritional composition of potato chips

The proximate composition of potato chip samples is presented in Table 2. There was a general decrease in the carbohydrate content with the incorporation of either soybean or moringa or both. Fibers and Ash contents showed a gradual increase with soybean inclusion and markedly with moringa and the combination of soybean and moringa. Except for potato chips with 15% moringa and 15% soybean (sample G), supplementation with soybean and/or moringa decreased the moisture content of the potato chips. Globally, the addition of either soybean and/or moringa during potato chips production increased the protein and fat contents with the highest content observed with 15% soybean (sample C) and 15% moringa and 15 % soybean (sample G). As compared to other samples, soybean-enriched potato chip samples displayed higher amounts of total calories.

**Table 2. Nutrient content of the processed potato products**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample** | **Carbohydrates (%)** | **Proteins (%)** | **Fats (%)** | **Fibers (%)** | **Moisture (%)** | **Ash (%)** | **Total Calories** |
| A | 79.7±0.11f | 6.62 ±0. 27a | 7.56±0.56a | 0.01±0.01a | 5.67±0. 22d | 0.44±0.02a | 413. 33±1.96c |
| B | 72.69±0.12d | 10.88±0.10d | 9.07±0.12b | 0.96±0.01b | 5.06±0.04d | 1.35±0.04b | 415.91±0.92c |
| C | 64. 28±0.26b | 12.56±0.07f | 13.94±0.07d | 0.97±0.01b | 4.78±0.02c | 3.47±0.41c | 432± 1.95d |
| D | 70.14±0.11c | 7.92±0.07b | 10.01±0.05c | 1.01±0.01b | 5.74±0.03d | 5.18±0.04d | 402±0.44b |
| E | 74.67±0. 42e | 8.00±0.01b | 8. 20±0.16a | 1.34±0.01c | 2.16±0.01a | 5.62±0.33d | 404.53±1. 25b |
| F | 66.57±0.77b | 9.62±0.32c | 12.02±0.04d | 1.77±0.06d | 3.80±0.09b | 6. 22±0.43d | 412.93±2.08c |
| G | 61.08±0.14a | 11.27±0.08e | 13.04±0.03d | 2.99±0.02e | 5.35±0.33e | 6. 26±0. 27d | 390.80±0.55a |

A: 100% potato, B: potato with 10% soybean, C: potato with 15% soybean, D: potato with 10% moringa, E: potato with 15% moringa and 10% soybean, F: potato with 10% moringa and 10% soybean, G: potato with 15% moringa and 15% soybean. Different subscripts within the same column differ significantly (*P*<.05).

**3.3 Mineral content of the processed potato products**

The analyses revealed a general increase in mineral content such as iron, calcium and potassium, especially with the inclusion of moringa alone or the combination moringa and soybean (Table 3). Globally there was a concentration increase of all minerals from sample D to sample G underscoring the mineral enrichment of potato chips with the addition of moringa alone or the mixture of both food additives. In contrast, the sample, lacking moringa and soybean, consistently had the lowest mineral content.

**Table 3. Mineral content of the processed potato products**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sample | Fe (mg/100g) | Zn (mg/100g) | Ca (mg/100g) | K (mg/100g) |
| A | 4.95±0.04b | 1.66±0.10d | 19.13±0.36c | 165.89±0.58a |
| B | 4.42±0.19b | 1.23±0.03b | 18.48±0.19b | 168.59±0.07b |
| C | 4.08±0.06a | 1.15±0.02a | 18.03±0.02a | 167.54±0.46b |
| D | 5. 25±0.06c | 1.62±0.02d | 20.5±0.07d | 169.98±0.61c |
| E | 5.84±0.11e | 1.36±0.01c | 21.10±0. 12e | 169.9±0.94c |
| F | 5.55±0.03d | 1.54±0.04d | 21.67±0.10f | 171.69±1.15c |
| G | 6.0±0.02e | 1.61±0.01d | 21.97±0.02g | 171.14±1.72c |

A: 100% potato, B: potato with 10% soy bean, C: potato with 15% soy bean, D: potato with 10% moringa, E: potato with 15% moringa and 10% soy bean, F: potato with 10% moringa and 10 % soy bean, G: potato with 15% moringa and 15% soy bean. Different subscripts within the same column differ significantly (*P*<.05).

## 3.4. Antioxidant content of potato chips

The evaluated antioxidant content of the processed chips included β-carotene and total phenolics content (Table 4). As far as β-carotenes are concerned, the addition of moringa powder and in combination with soybean significantly (*P*<.05) concentration-dependently increased the β-carotene content of the potato chips. Sample G showed the highest value of Beta- carotene (*P*<.05), follow respectively by samples F and E. The other samples had similar values (*P*>.05). In general, enrichment with soybean alone did not have any effect on Beta–Carotene of potato chips while the presence of moringa led to an increase.

As far as phenolic compounds are concerned, Sample C indicated the lowest (*P*<.05) total phenolic content and sample G the highest (*P*<.05). Globally, soybean alone lowered (*P*<.05) the total phenolic content while it was increasing significantly (*P*<.05) in presence of moringa

**Table 4. β-carotene and total phenolic content of processed potato snacks.**

|  |  |  |
| --- | --- | --- |
| **Sample** | **β-carotene (mg/ 100g)** | **Total phenolic content (mg GAE/g)** |
| A | 0.01±0.01a | 14.47±0.31c |
| B | 0.01 ±0.0a | 7.43 ±0.04b |
| C | 0.02 ±0.01a | 5.59±0.03a |
| D | 0.03 ±0.01a | 16.05±0.11d |
| E | 0.11 ±0.02b | 19. 27±0.04e |
| F | 0.32 ±0.05c | 16.69±0.0.13d |
| G | 0.58 ±0.03d | 20.75±0.17f |

A: 100% potato, B: potato with 10% soy bean, C: potato with 15% soy bean, D: potato with 10% moringa, E: potato with 15% moringa and 10% soy bean, F: potato with 10% moringa and 10 % soy bean, G: potato with 15% moringa and 15% soy bean. Different subscripts within the same colunmn differ significantly (*P*<.05)

**4. DISCUSSION**

Diseases due to inadequate or limited effective nutrients are responsible for or associated to with numerous health affections including both communicable and non-communicable diseases. The burden of such diseases is particularly important among vulnerable groups (children, and pregnant women) in developing countries such as Cameroon (Echouffo-Tcheugui and Kengne 2011; Kyu et al. 2018; WHO 2023). Food enrichment is a delicate process which that can results in a positive or negative impact of on different physicochemical properties of the final product (Igual and Martínez-Monzó 2022). The study was then designed to produce an enriched snack from potatoes using moringa leaf powder and soybean flour as a nutrient source with a goal of contributing to contribute to the fight against health and nutritional nutritional-related diseases using an enriched commonly consumed foods in this case which potato chips.

The incorporation of either soy bean or moringa or both decreased the carbohydrate and moisture contents while increasing, protein, fat, fibers, and ash levels in potato chips. Carbohydrates are large and abundant biomolecules used as first first-line for their nutritive and cell structural properties (Chinaza and Ikechukwu 2021). It is the main the constituents of starchy foods especially Irish potatoes and one of the main staple foods consumed worldwide including Cameroon. The substantial decrease of in carbohydrates particularly upon incorporation of moringa could favor the utilization of a formula by people that necessitate the consumption of less starchy foods such as diabetic patients. Proteins and fats represent key compounds used in the biosynthesis of vital biomolecules such as structural proteins, cell membranes, enzymes, vitamins, antibodies, and hormones (Singh et al. 2017; Morris et al. 2022). Fibers are non-digestible (by humans) carbohydrate polymers that play important biological functions including improving the digestive tract health, and prevention, control, and reduction of cases of metabolic and chronic diseases (Barber et al. 2020). Ash constitutes the inorganic portion of a given food obtained from the burning of the organic constituents. It is directly proportionate to the food's total mineral content (Monti et al. 2008). The increase of the protein, fat, fibers, ash and mineral contents in obtained potato chips could be due to the richness of moringa and the combination moringa - soy bean in these nutrients. Consistently authors have revealed a high content of soy bean and moringa in fibers, proteins, and minerals (Abbas et al. 2018; Bayero et al. 2019). Comparatively, moringa is rich in minerals namely K, S, Ca, and Fe with Ca and Fe being highly bioaccessible (Peñalver et al. 2022). The increase in mineral content of enriched potatoes chips underscores the effectiveness of moringa and in mixture with soybean flour in enhancing food nutritional value and thus a viable strategy for boosting essential minerals like iron, potassium, and calcium.

The supplemented ingredients, particularly moringa as from 15% incorporation or in combination with soy bean resulted in significantly increased contents of the evaluated antioxidants (β-carotene, total phenolics). The essential source of antioxidants in enriched potato chips seems to originate from moringa powder rather than soy bean flour as the latter alone displayed no or decreased antioxidant contents in the present processed food. In fact moringa leaves have been shown to possess noticeable amounts of antioxidants including phenolic compounds and the pro-vitamin A, β-carotene (Ali et al. 2022; Peñalver et al. 2022). Phenolic compounds are a large group of secondary metabolites containing hydroxyl group on the aromatic ring and displaying different biological functions such as anti-inflammatory, antioxidant, antimicrobial, anticancer, antidiabetic, neuroprotective, and cardioprotective properties (Sauceda et al. 2017). Consequently, the present enriched potato chips especially those supplemented with 15% moringa and the moringa/soy bean could be promising options for individuals suffering or at risk of vitamin A deficiency or oxidative stress stress-related diseases.

The sensory attributes constitute a qualitative appreciation of a given food item by selected panelists, this for with the overall goal to of providing some orientations to a the possible acceptability of a product (Ruiz-Capillas et al. 2021). Out of the potato chip samples, those enriched with soy bean flour maintained the sensory attributes while the inclusion of moringa flour tended to lower these properties. The decreased appreciation of moringa-based potato chips is consistent with the bitterness taste due to the glucosinolates and saponins present in the leaves of this plant (Divya et al. 2024). All together considering the sensory attributes, and nutritional and biological (antioxidant) properties, potato chips enriched with the combination of moringa and soy bean seems to display some synergistic traits notably concerning the nutrient and antioxidant contents though they were less appreciated by the panelists. However, the actual synergistic interaction between the bioactive compounds in both food ingredients still necessitates further investigations.

**5. CONCLUSION**

In conclusion, potato chips enriched with either moringa powder, soy bean flour, or the mixture of both display distinct nutritional, antioxidant, and sensory properties. Combined moringa and soy bean-based potato chips demonstrated striking nutrient and antioxidant contents that support their potential consideration in the prevention or management of related health affections within our communities.

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