Preparation and Evaluation of High Nutrition Value Crackers Enriched With Some Leafy Vegetables

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ABSTRACT

The present study is carried out to evaluate the nutritional, functional, and sensorial properties of crackers enriched with green leafy vegetables powder (GLVP) namely (chicory, dill, coriander, parsley, and rocket) at 5, 10 and 15 % replacement of dried leaves/100 g wheat flour. Crackers were found to be nutritionally rich in protein, fiber, minerals and antioxidant activity compared with control crackers. Sensory properties of crackers showed that up to 10% wheat flour replacement of green leaves powder were acceptable. Results showed that the highest content of protein observed in crackers with 10% parsley, the highest content of ash was in crackers with 10% dill and the highest content of crude fiber and fat content in crackers with 10% chicory compared with control. There was a significant increment in the antioxidant activity with the addition of green leaves powder. The highest content of antioxidant activity and total phenolic content of prepared crackers with dill (38.64% -83.06 mg /100g) respectively, but the highest content of total Flavonoids in crackers with 10% chicory (67.5 mg /100gm). The highest content of chlorophyll a was in the crackers with 10% rocket and the lowest content in the crackers with 10% dill but the highest content of chlorophyll b was in the crackers with 10% coriander and the lowest was in crackers with 10% dill on the other hand the highest carotenoids was in the crackers with 10% coriander but the lowest was in crackers with 10% dill.

1. Introduction

As a result of the increasing demand for functional foods, companies have led to the tendency to manufacture new products with nutritional value which considers a source of bioactive compounds. Green leafy vegetables are considered rich in total phenolic contents, flavonoids, pigments, carotenoids, and antioxidant activity (Zeb, 2017). In addition, it is an excellent source of water-soluble vitamins and vitamin A as well as minerals (like calcium, iron, zinc, and phosphorus), fiber, which have biological effect in human health (Kavitha and Ramadas, 2013) and (Natesh et al., 2017). These effects include those that are anticancer (Vinholes and Vizzotto, 2017), antidiabetic (Maser et al., 2023), anti-obesity (Paul and Majumdar, 2022), antimicrobial, anti-Alzheimer's disease (Eruygur et al., 2019), anti-tyrosinase activity (Blahova et al., 2021) and reducing cholesterol levels (Otles and Ozgoz, 2014). Chicory (Cichorium intybus L.) is a species of the Asteraceae family and is considered an annual plant. Dried roots are added to coffee to enhance flavor and fresh leaves can be added to salads and vegetable dishes (Jurgo et al., 2011). The plant reportedly has a significant source of chicoric acid and dietary fiber. By the side of, chicory contains saccharides, organic acids, polyphenols such as chlorogenic and caffeic acid (Denev et al., 2014). Numerous clinical research have verified the health benefits of chicory and its products, which includes modification of gut microflora, improving immune response, Appetite control and body weight, mineral absorption, body...
weight, mineral absorption, and bone health (Micka et al., 2017). Dill (Anethum graveolens L.) is a species of the Apiaceae family and is fragrant herb that is used for flavoring various foods, including salads, sauces, soups and sea foods. Furthermore, dried dill leaves are utilized in conventional herbal medicine. Dill is utilized to treat some gastrointestinal disorders and many digestive problems (Derakhshan et al., 2017). Various compounds found in dill including vitamin C and polyphenols, which enhance its anticancer properties (Craig, 2021). Dill rich in minerals (Gautam et al., 2013) contains vitamin A plus fiber, which play an important role in regulating cholesterol and digested carbohydrates, (Hammad et al., 2019). Coriander (Coriandrum sativum) is a species of the Apiaceae family and is considered a valuable herb and has a pleasant aromatic odor. Leaves are particularly rich in vitamin A, vitamin C, and vitamin K, with a moderate of elements content (Dhanapakiam et al., 2008). Coriander improves digestion and treating gastrointestinal disorders (Jabeen et al., 2009). Dry coriander reduces acidity and cure diarrhea (Kaium, 2013). This plant has a wide range of biological effects including antioxidant activity, anti-diabetic, anti-microbial activity, anti-convulsant activity, hypnotic activity, anti-helminthic, and anti-mutagenic activity (Aissaoui & Lyoussi, 2011 and Rajeshwari & Andalu, 2011).

Parsley (Petroselium crispum) is a species of the Apiaceae family and utilized as an aromatic food additive and flavoring (Zhang et al., 2006). Parts of Parsley are rich in minerals like iron, zinc, calcium, and phosphorous, also contain fatty acids like linolenic and palmitic acid, furanocoumarins, essential oils, flavonoids, carotenoids, vitamins like tocopherols, A, C, and B complex, (Petropoulos et al., 2008). Parsley has various biological effects in human health such as antioxidant activity, hepatoprotective, antibacterial, antifungal, analgesic, diuretic, hypotensive and gastroprotective (Farzaei et al., 2013). It also helps control immune diseases such as inflammation, anemia, hyperlipidemia, diabetes as well as lessen the symptoms of allergies, chronic bronchitis, dyspepsia, hypotension, thrombosis, and stroke. (El-Sayed et al., 2018 and Chauhan et al., 2018). Rocket (Eruca sativa) is a species of the Brassicaceae family. It is a medicinal plant that is characterized by its pleasant bitter taste. (Khoobchandani et al., 2011). Vitamin C is abundant in Rocket leaves along with other vitamins, such as vitamins A, K, B complex (Gutiérrez et al., 2018). It also contains many bioactive compounds, mainly glucosinolates and polyphenolic compounds (Sut et al., 2018). High mineral content, and many health-promoting substances (Esiyok et al., 2010). It was used as an innovative cancer prevention agent and potent active component plant that may improve human health (Michael, 2011). Crackers are a kind of crunchy, crispy and thin baked snack food. They are prepared with a blend of flour, water, and other ingredients, such as salt, sugar, yeast, oil, or butter. Crackers are available in different shapes and sizes, and they can be plain or flavored with cheese herbs or spices (Manley, 2011). The objective of this work was to study the nutritional and functional of some dried green leafy vegetables (Chicory, Dill, Coriander, Parsley, and Rocket) powders in cracker manufacturing and the effect of adding these dried leaves on the sensory properties, nutritional and functional attributes of crackers.

Materials and Methods

Materials

-Fresh chicory, dill, coriander, parsley, and rocket were obtained from the local market in Zaqzig, Sharqia governorate, Egypt.

-Wheat flour of 72% extraction rate, table salt, sodium bicarbonate, and vegetable oil required for the preparation of crackers were obtained from the local market. All chemicals used were of analytical reagent grade.

Methods

Preparation of raw materials

-Fresh chicory, dill, coriander, parsley, and rocket leaves were washed, then cut to thin slices and air dried then, completely dried in an oven with a fan at 50°C for 15:20 minutes. Net weights after drying (100 g) leaves were (14.36, 12.48, 13.24, 13.60 and 14.08 g).
The dried leaves were milled and sieved at 72 mesh (around 210 μm) then kept in an airtight jar and stored in dry place.

**Analytical methods**

**Chemical analysis of dried leaves and prepared crackers**

Moisture, protein, crude fiber, fat, and ash were determined according to methods cited in the (AOAC, 2016). The total carbohydrate content was calculated according to the following formula:

\[
\text{Total carbohydrates content } \% = (100 - \text{ash}% + \text{fat}% + \text{crude protein}% + \text{crude fiber }\%)
\]

According to (James 1995), the following formula was used to determine the meal formulation's overall energy value:

\[
\text{Total energy (kcal/100g)} = [\text{(% carbohydrates } \times 4) + \text{(% protein } \times 4) + \text{(% fat } \times 9)]
\]

Elemental analysis for iron, calcium, and zinc was determined by using an atomic absorption spectrophotometer as described in (AOAC, 2019).

**Total phenols and flavonoids determination**

According to (Singleton and Rossi, 1965) total phenol content was determined using the Folin-Ciocalteu method. The absorbance was read at 765 nm using gallic acid as a standard. Total flavonoids were determined using the aluminum chloride colorimetric method, as described by (Chang et al., 2002).

**Determination photosynthetic pigment**

Chlorophyll a, chlorophyll b, and total carotenoids contents (mg/g dry weight) were determined according to the method mentioned by (Gogoi & Basumatary 2018 and Nagata & Yamashita 1992).

**Antioxidant activity**

The antioxidant activity of dried leaves and crackers samples was measured by a DPPH assay. The antioxidant activity was evaluated by the 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging method according to the procedure of (Chen et al., 2008). The percentage inhibition of the DPPH radical by the samples was calculated according to the following equation:

\[
\text{DPPH radical-scavenging activity (\%)} = \frac{[(A - B)/A]}{100}.
\]

Where, A is the absorbance of the control and B is the absorbance of the samples.

**Technological properties**

**Preparation of crackers**

The crackers enriched with different levels of green leafy vegetable powder were prepared using wheat flour (72% extraction rate) as the control and with 5, 10, and 15% replacement of dried leaves/100 g wheat flour as follow:-, sodium bicarbonate (1g), salt (2g), sugar (1g), were mixed, then oil (20 ml), and water (15 ml) were added according to the method mentioned by AACC (2000) with some modifications. Then, the dough was formed into a thin layer and shaped into triangles. It was baked in an oven for 15 minutes at 180°C.

**Physical characteristics of crackers**

Crackers enriched with different levels of green leafy vegetable powder were evaluated for their physical characteristics (weight, volume, and thickness) parameters according to (AACC 2004), and bulk density was measured according to (Abd Elmoneim et al., 2005).

**Texture Profile Analysis (TPA)**

The texture of the Crackers was carried out using the Brookfield CT3 instrument (Brookfield Engineering Laboratories, Inc., MA 02346-1031, USA) according to the method outlined in the AACC (2010). Both hardness which relates to the “force applied by the molar teeth to compress the food”, and fractur ability which relates to the “ability to break food into pieces when it is bitten using the incisors” were expressed in Newton (N). The following test settings were used:

Target = 3.0 mm, trigger load = 3.00 N, test speed = 3.00 mm/s, return speed = 3 mm/s, and number of cycles = 1.0.

**Color measurement**

The colorimetric measurements for crackers were measured in triplicate using a colorimeter (CR-10, Konica Minolta Sensing Inc., Japan), according to (McGurie, 1992). The color values were recorded as: \( L^* = \text{lightness} (0 = \text{black}, 100 = \text{white}), a^* (-a^*...
greenness, \( +a^* \) = redness), and \( b^* \) (-b* = blue-
ness, \( +b^* \) = yellowness).

### Determination of water activity \( (a_w) \)

Water activity was measured at 25±2 °C using a
Decagon Aqualab meter series 3TE (Pullman, WA,
USA). All crackers samples were broken into small
pieces immediately before water activity measure-
ment (Shahidi et al., 2008).

### Sensory evaluation

Sensory evaluations for crackers enriched with
different levels of GLVP were carried out by 10
members of the Crops Technology Department,
Food Technology Research Institute, Agricultural
Research Center, Giza, Egypt. The judges were
asked to give a score color, flavor, smell, appear-
ance, crispiness and overall acceptability on a 9-
hedonic scale from one (dislike extremely) to nine
(like extremely) according to (Akonor
et al., 2016) with slightly modification.

### Statistical analysis

The data obtained (mean of three replicates) were
statistically analyzed according to statistical analyses
system user’s guide (SAS, 2004). Analysis of variance
(ANOVA) and Duncan’s multiple comparison pro-
cedure were used to compare the means. A probability
of \( p<0.05 \) was used to establish statistical signifi-
cance.

### Results and Discussion

#### Chemical composition of green leafy vege-
tables powder (GLVP)

Nutritional composition of GLVP is shown in
Table 1. It could be noticed that dried parsley leaves
had the highest values of both fat (4.00%) and pro-
tein (21.88%). dried chicory leaves recorded the
highest values of moisture and crude fiber (8.05 and
10.05%, respectively), and dried rocket and parsley
leaves recorded the highest values of ash (12.5% and
11.8%, respectively). These results are
confirmed by those obtained by (El Shewey et al.,
2005 and Amer et al., 2009). Results also indicate
that rocket leaf powder has high amounts of ele-
ment content. On the other hand, the highest content
of calcium and iron was found in dried rocket and parsley leaves (873.71 and 816.29 mg/100g) and
69.14 and 61.56 mg/100g, respectively, while zinc
was found in dried rocket and dill leaves (11.78 and
8.55 mg/100g, respectively). These results agreed
with (El Shewey et al., 2005), who reported that
chicory leaves have minerals like calcium, zinc, and
iron (853.77, 5.72, and 84.28 mg/100 g, respective-
ly), (Georgi et al., 2018), who confirmed that Bul-
garian and Italian rockets have zinc of (9.105, 1.507
mg/100g, respectively), and (Deepali and Roji
2020), who investigated that coriander leaf powder
was rich in essential element content like calcium
(2805.46 mg/100g) and iron (42.1mg/100g) in
which there are variation in calcium content may be
as a result of different environmental condition like
temperature, soil type and fertilization.

#### Total phenolics, Total flavonoids, chloro-
phyll a and b, total carotenoids content,
and antioxidant activity of green leafy
vegetables powder (GLVP)

Total phenolic compounds found in plants
which increase the natural antioxidants in human
diets when consumed plant- based foods
(Balasundram et al., 2006). Results in Table 2.
showed that the total phenolic content of all green
leafy vegetables powder was around 85 to 90
mg/100 g, with dill having the highest content
(90.35 mg/100g) and coriander having the lowest
content (85.94 mg/100g). Results also showed that
chicory and coriander leaves had the highest con-
tent of total flavonoids (9.07 and 9.00 mg/100g),
while parsley leaves contained the lowest content
(4.5 mg/100g). From the same table, the highest
value of chlorophyll a was in coriander leaves and
the lowest value in dill and rocket leaves, but the
highest value of chlorophyll b was in chicory leaves
and the lowest value in parsley leaves. On the other
hand, the highest carotenoid was in chicory and co-
riander leaves, but the lowest was in dill. Results in
Table 2. showed the highest value of the antioxidant
activity was in dill and chicory leaves (86.40 and
86.13%), while the lowest value was in coriander
leaves (84.26%). These findings of antioxidant
activity are confirmed by those of (Deepali and Roji
2020), who proved that the scavenging activity of
coriander leaf powder was 93.34%.
Table 1. Nutritional composition of green leafy vegetables powder (g/100g dry weight basis)

<table>
<thead>
<tr>
<th>Dried green leaves</th>
<th>Moisture %</th>
<th>Ash %</th>
<th>Protein %</th>
<th>Crude Fiber %</th>
<th>Fat %</th>
<th>Total Carbohydrates %</th>
<th>Element content (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicory</td>
<td>8.05±0.01</td>
<td>10.90±0.19</td>
<td>20.46±0.05</td>
<td>10.05±0.02</td>
<td>3.90±0.13</td>
<td>54.69±0.22</td>
<td>Calcium: 745.54±0.37, Zinc: 7.60±0.07, Iron: 57.50±0.12</td>
</tr>
<tr>
<td>Dill</td>
<td>6.90±0.12</td>
<td>10.50±0.16</td>
<td>21.17±0.02</td>
<td>9.16±0.01</td>
<td>2.50±0.19</td>
<td>56.67±0.21</td>
<td>Calcium: 720.54±0.46, Zinc: 8.55±0.07, Iron: 41.01±0.03</td>
</tr>
<tr>
<td>Coriander</td>
<td>7.26±0.01</td>
<td>9.60±0.18</td>
<td>18.91±0.07</td>
<td>9.45±0.05</td>
<td>3.60±0.18</td>
<td>58.44±0.22</td>
<td>Calcium: 575.02±0.04, Zinc: 8.13±0.04, Iron: 41.48±0.01</td>
</tr>
<tr>
<td>Parsley</td>
<td>6.70±0.10</td>
<td>11.80±0.19</td>
<td>21.88±0.04</td>
<td>9.05±0.03</td>
<td>4.00±0.15</td>
<td>53.37±0.20</td>
<td>Calcium: 816.29±0.47, Zinc: 7.44±0.03, Iron: 61.56±0.01</td>
</tr>
<tr>
<td>Rocket</td>
<td>7.50±0.10</td>
<td>12.50±0.14</td>
<td>19.48±0.02</td>
<td>9.95±0.03</td>
<td>3.90±0.13</td>
<td>54.17±0.19</td>
<td>Calcium: 873.71±0.01, Zinc: 11.78±0.04, Iron: 69.14±0.07</td>
</tr>
</tbody>
</table>

Data are presented as means ± SDM (n=3) & Means within a column with different letters are significantly different at P ≤ 0.05.

Table 2. Total phenolic, Total Flavonoids, chlorophyll a and b, Total carotenoids content and Antioxidant activity, of green leafy vegetables powder.

<table>
<thead>
<tr>
<th>Dried green leaves</th>
<th>Total phenolic (mg/100gm)</th>
<th>Total Flavonoids (mg/100gm)</th>
<th>Chl. a (mg/g)</th>
<th>Chl. b (mg/g)</th>
<th>Total Carotenoids (mg/g)</th>
<th>Antioxidant activity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicory</td>
<td>90.09±1.46</td>
<td>9.07±1.02</td>
<td>0.488±0.002</td>
<td>1.25±0.001</td>
<td>0.238±0.003</td>
<td>86.13±0.075</td>
</tr>
<tr>
<td>Dill</td>
<td>90.35±1.56</td>
<td>8.50±1.2</td>
<td>0.461±0.001</td>
<td>1.126±0.002</td>
<td>0.221±0.001</td>
<td>86.40±0.377</td>
</tr>
<tr>
<td>Coriander</td>
<td>85.94±0.81</td>
<td>9.00±0.2</td>
<td>0.496±0.003</td>
<td>1.229±0.001</td>
<td>0.238±0.002</td>
<td>84.26±0.105</td>
</tr>
<tr>
<td>Chicory</td>
<td>87.80±1.47</td>
<td>4.50±2.2</td>
<td>0.481±0.002</td>
<td>1.158±0.002</td>
<td>0.229±0.002</td>
<td>85.75±0.16</td>
</tr>
<tr>
<td>Rocket</td>
<td>86.53±1.24</td>
<td>5.91±1.03</td>
<td>0.462±0.001</td>
<td>1.216±0.001</td>
<td>0.236±0.001</td>
<td>85.50±0.03</td>
</tr>
</tbody>
</table>

Data are presented as means ± SDM (n=3) & Means within a column with different letters are significantly different at P ≤ 0.05.

Sensory evaluation of crackers enriched with green leafy vegetables powder (GLVP)

Crackers enriched with different levels of green leafy vegetable powder (GLVP) were evaluated for their sensory qualities and overall acceptability, as presented in Table (3). Results show that there is no significant effect in samples enriched with 5% or 10% with (GLVP) and control sample in overall acceptability. The results of sensory evaluations indicated that sensory qualities and overall acceptability scores of crackers decreased by increased levels of (GLVP) up to 10% replacement in samples as compared to control sample (100% wheat flour). Also, there are no significant differences between control sample and other samples enriched with 10% (GLVP) in flavor, appearance and overall acceptability. Therefore, it could be recommended that it could produce crackers with good quality and acceptable sensory quality attributes with enriched up to 10 % of (GLVP). Those results agree with (Jyoti, et al., 2022) who investigated that cookies and biscuits were found acceptable up to 10 % level of fortification of green leafy vegetables.

Physical properties of crackers enriched with (GLVP)

Physical properties weight (g), volume (cm^3), bulk density (g/cm3), and thickness (mm) are important for both manufacturers and consumers. Table 4. shows the physical properties of the resultant crackers prepared from a mixture of wheat flour and 10% GLVP replacement for several physical characteristics. There was a significant increment in the weight, volume, and bulk density of cracker samples, especially with chicory, after supplementation (17.21g, 30.5cm^3, and 0.65g/m^3, respectively) compared with the control cracker sample (100% wheat flour) (11.96g, 15.0cm^3, and 0.55g/cm^3), respectively. This increase might be due to an increase in fiber and protein content in the prepared crackers. Similar results were obtained by (Yadav 2022). The thickness of the control crackers and the enriched crackers was 2.50, 1.95, 2.00, and 2.20 mm. (Johry et al., 2016) explained the increase in the high-water holding capacity of the additive.
Table 3. Sensory evaluation of crackers enriched with green leafy vegetables powder

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Color (9)</th>
<th>Smell (9)</th>
<th>Flavor (9)</th>
<th>Appearance (9)</th>
<th>Crispness (9)</th>
<th>Overall Acceptability (9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>8.33 ± 1.816</td>
<td>8.33 ± 0.82</td>
<td>8.00 ± 1.10</td>
<td>8.00 ± 1.10</td>
<td>8.08 ± 1.02</td>
<td>8.16 ± 0.52</td>
</tr>
<tr>
<td>Chi 1</td>
<td>6.82 ± 1.84</td>
<td>7.33 ± 2.25</td>
<td>7.83 ± 1.17</td>
<td>6.75 ± 1.89</td>
<td>8.00 ± 0.89</td>
<td>7.66 ± 0.03</td>
</tr>
<tr>
<td>Chi 2</td>
<td>5.75 ± 2.57</td>
<td>6.16 ± 1.84</td>
<td>6.50 ± 1.52</td>
<td>6.50 ± 2.43</td>
<td>7.66 ± 1.03</td>
<td>7.40 ± 1.36</td>
</tr>
<tr>
<td>Chi 3</td>
<td>4.91 ± 2.50</td>
<td>5.83 ± 1.94</td>
<td>6.00 ± 1.41</td>
<td>5.83 ± 2.14</td>
<td>6.50 ± 1.05</td>
<td>6.33 ± 1.37</td>
</tr>
<tr>
<td>Par 1</td>
<td>6.33 ± 2.16</td>
<td>6.41 ± 1.91</td>
<td>6.25 ± 1.78</td>
<td>6.91 ± 1.28</td>
<td>7.33 ± 1.03</td>
<td>7.00 ± 1.10</td>
</tr>
<tr>
<td>Par 2</td>
<td>6.00 ± 1.90</td>
<td>6.50 ± 1.05</td>
<td>6.33 ± 1.63</td>
<td>6.33 ± 1.47</td>
<td>7.41 ± 1.36</td>
<td>6.79 ± 1.72</td>
</tr>
<tr>
<td>Par 3</td>
<td>5.50 ± 2.43</td>
<td>6.66 ± 1.75</td>
<td>6.66 ± 1.63</td>
<td>6.33 ± 1.97</td>
<td>7.00 ± 1.055</td>
<td>6.33 ± 1.51</td>
</tr>
<tr>
<td>Cor 1</td>
<td>6.00 ± 1.41</td>
<td>6.50 ± 1.23</td>
<td>6.33 ± 1.63</td>
<td>6.00 ± 1.33</td>
<td>7.16 ± 1.17</td>
<td>7.16 ± 1.17</td>
</tr>
<tr>
<td>Cor 2</td>
<td>6.16 ± 2.14</td>
<td>7.00 ± 0.89</td>
<td>6.50 ± 1.64</td>
<td>6.33 ± 1.97</td>
<td>7.3 ± 1.21</td>
<td>7.41 ± 1.02</td>
</tr>
<tr>
<td>Cor 3</td>
<td>6.00 ± 2.28</td>
<td>6.5 ± 1.64</td>
<td>6.50 ± 1.05</td>
<td>6.33 ± 1.51</td>
<td>7.50 ± 1.38</td>
<td>6.50 ± 1.23</td>
</tr>
<tr>
<td>Dil 1</td>
<td>7.08 ± 1.36</td>
<td>6.66 ± 1.37</td>
<td>6.83 ± 1.47</td>
<td>7.00 ± 1.67</td>
<td>7.66 ± 0.99</td>
<td>7.00 ± 1.27</td>
</tr>
<tr>
<td>Dil 2</td>
<td>6.16 ± 2.32</td>
<td>6.58 ± 0.92</td>
<td>6.41 ± 1.56</td>
<td>7.00 ± 1.41</td>
<td>7.41 ± 1.02</td>
<td>7.16 ± 1.17</td>
</tr>
<tr>
<td>Dil 3</td>
<td>5.50 ± 1.87</td>
<td>6.5 ± 1.38</td>
<td>6.33 ± 1.63</td>
<td>6.58 ± 1.63</td>
<td>7.25 ± 1.61</td>
<td>6.50 ± 0.64</td>
</tr>
<tr>
<td>Roc1</td>
<td>6.61 ± 1.02</td>
<td>5.77 ± 0.75</td>
<td>6.16 ± 0.75</td>
<td>6.61 ± 0.49</td>
<td>6.16 ± 0.75</td>
<td>6.82 ± 0.41</td>
</tr>
<tr>
<td>Roc2</td>
<td>6.22 ± 0.40</td>
<td>6.04 ± 1.14</td>
<td>6.11 ± 0.78</td>
<td>6.16 ± 0.41</td>
<td>6.16 ± 0.75</td>
<td>6.61 ± 0.80</td>
</tr>
<tr>
<td>Roc3</td>
<td>5.61 ± 1.18</td>
<td>5.94 ± 0.91</td>
<td>6.00 ± 0.00</td>
<td>6.55 ± 0.50</td>
<td>6.16 ± 0.75</td>
<td>6.11 ± 0.17</td>
</tr>
</tbody>
</table>

In which, Control: cracker with 100% wheat flour, Chi 1, 2, 3: cracker with 5, 10 and 15% chicory powder; Par 1, 2, 3: cracker with 5, 10 and 15% Parsley powder; Cor 1, 2, 3: cracker with 5, 10 and 15% Coriander powder; Dil 1, 2, 3: cracker with 5, 10 and 15% dill powder and Roc 1, 2, 3: cracker with 5, 10 and 15% rocket powder.

Data are presented as means ± SDM (n=10) & Means within a column with different letters are significantly different at P ≤ 0.05.

Figure 1. Crackers enriched with green leafy vegetables powder.

In which, Control: cracker with 100% wheat flour. Chi2: cracker with 10% chicory powder. Par2: cracker with 10% parsley powder. Cor2: cracker with 10% coriander powder. Dil2: cracker with 10% dill powder. Roc2: cracker with 10% rocket powder.

Table 4. Physical properties of crackers enriched with green leafy vegetables powder

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Weight (g)</th>
<th>Volume (cm³)</th>
<th>Bulk density (g/cm³)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>11.96 ± 0.28</td>
<td>15.0 ± 0.6</td>
<td>0.55 ± 0.005</td>
<td>2.50 ± 0.01</td>
</tr>
<tr>
<td>Chi 2</td>
<td>17.21 ± 0.99</td>
<td>30.5 ± 0.5</td>
<td>0.65 ± 0.005</td>
<td>1.95 ± 0.01</td>
</tr>
<tr>
<td>Par 2</td>
<td>14.88 ± 1.02</td>
<td>21.5 ± 0.5</td>
<td>0.69 ± 0.1</td>
<td>2.00 ± 0.02</td>
</tr>
<tr>
<td>Cor2</td>
<td>14.84 ± 1.07</td>
<td>29.5 ± 0.5</td>
<td>0.56 ± 0.2</td>
<td>2.00 ± 0.01</td>
</tr>
<tr>
<td>Dil2</td>
<td>15.65 ± 1.35</td>
<td>30.5 ± 0.5</td>
<td>0.50 ± 0.1</td>
<td>2.00 ± 0.02</td>
</tr>
<tr>
<td>Roc2</td>
<td>12.20 ± 0.4</td>
<td>19.9 ± 1</td>
<td>0.60 ± 0.05</td>
<td>2.20 ± 0.02</td>
</tr>
</tbody>
</table>

In which, Control: cracker with 100% wheat flour. Chi2: cracker with 10% chicory powder Par2: cracker with 10% parsley powder. Cor2: cracker with 10% coriander powder. Dil2: cracker with 10% dill powder. Roc2: cracker with 10% rocket powder.

Data are presented as means ± SDM (n=3) & Means within a column with different letters are significantly different at P ≤ 0.05.
Proximate chemical composition of crackers enriched with (GLVP)

The proximate chemical composition of the produced crackers enriched with (GLVP) is presented in Table 5. Moisture, protein, fat, crude fiber, and ash of crackers made from wheat flour (control) were found to be significantly increased with the addition of (GLVP). The result revealed that enriched crackers would be of better quality as compared with 100% wheat flour crackers. The highest value of protein was observed in (Par 2) the sample with 10% parsley, the highest value of ash was in (Dil 2) the sample with 10% dill, and the highest value of crude fiber and fat content was in (Chi 2) the sample with 10% chicory, while the highest total carbohydrate and total energy were observed in the control. The decrease in carbohydrate content as the supplementation with dried green leaves increased may be due to the low carbohydrate content in dried green leaves. These results are similar to those of (Deepali and Roji, 2020). The highest values of total carbohydrate and total energy were observed in the control sample.

Table 5. Proximate chemical composition of crackers enriched with green leafy vegetables powder

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Moisture %</th>
<th>Ash %</th>
<th>Protein %</th>
<th>Crude fiber %</th>
<th>Fat %</th>
<th>Total Carbohydrates %</th>
<th>Total energy (kal/100gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.0±0.13</td>
<td>0.46±0.01</td>
<td>11.35±0.04</td>
<td>0.56±0.12</td>
<td>15.02±0.01</td>
<td>72.57±0.12</td>
<td>470.86±0.5</td>
</tr>
<tr>
<td>Chi 2</td>
<td>3.7±0.15</td>
<td>1.1±0.1</td>
<td>13.98±0.02</td>
<td>3.9±0.14</td>
<td>15.9±0.10</td>
<td>65.12±0.12</td>
<td>459.50±0.5</td>
</tr>
<tr>
<td>Par 2</td>
<td>4.5±0.19</td>
<td>0.86±0.01</td>
<td>14.49±0.03</td>
<td>1.8±0.17</td>
<td>15.8±0.14</td>
<td>67.05±0.03</td>
<td>468.36±0.9</td>
</tr>
<tr>
<td>Cor2</td>
<td>4.1±0.17</td>
<td>1.01±0.01</td>
<td>14.27±0.02</td>
<td>3.4±0.11</td>
<td>15.4±0.12</td>
<td>69.92±0.03</td>
<td>459.36±0.9</td>
</tr>
<tr>
<td>Dil 2</td>
<td>4.1±0.14</td>
<td>1.3±0.1</td>
<td>13.84±0.04</td>
<td>2.5±0.18</td>
<td>15.4±0.13</td>
<td>66.96±0.12</td>
<td>461.80±1.3</td>
</tr>
<tr>
<td>Roc2</td>
<td>3.8±0.13</td>
<td>0.99±0.02</td>
<td>13.31±0.02</td>
<td>3.7±0.16</td>
<td>15.7±0.15</td>
<td>66.30±0.2</td>
<td>459.73±0.04</td>
</tr>
</tbody>
</table>

In which, Control: cracker with %100 wheat flour. Chi 2: cracker with 10% chicory powder. Par 2: cracker with 10% parsley powder. Cor 2: cracker with 10% coriander powder. Dil 2: cracker with 10% dill powder. Roc 2: cracker with 10% rocket powder.

Textural properties and water activity of crackers enriched with (GLVP)

Texture is an important factor that affects the final product acceptability. Texture analysis is used to determine the hardness of the product (Gumte et al., 2018). The data in Table 6. showed that hardness and fracturability decreased with the addition of GLVP compared with the control (77.92 N). The results are in agreement with the work by (Thanaa et al., 2019 and Afify, 2022). The crackers enriched with green leafy vegetables showed a significant difference in a_w; the value of a_w ranged from 0.184–0.364 in present study. The highest value of a_w was in (Roc 2) crackers enriched with 10% rocket (0.364) when compared with the control (0.264). All samples presented showed values of a_w less than 0.50. (Fontana, 1998) demonstrated that the measurement of water activity can help predict food stability and safety in terms of microbial growth, deterioration reactions, and chemical and physical characteristics.

The color properties of crackers enriched with green leafy vegetable powder are presented in Table 6 in terms of L*, a*, and b* values. The lightness values were in the range of 47.59 to 84.33, which was significantly reduced by the addition of green leafy vegetable powder compared to the control. a* values varied between -0.80 and -4.90, indicating significant increases in the green color of the crackers as the wheat flour was partially replaced with GLVP. a* values were significantly increased with the incorporation of dill and rocket powder. On the other hand, b* values varied between 12.76 and 20.42 as the proportion of green leafy vegetable powder increased due to the green and yellow colors originating from green leafy vegetable powder.
Table 6. Water activity, textural properties and color properties of crackers

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Water activity (aw)</th>
<th>Hardness (N)</th>
<th>Fracturability (N)</th>
<th>color properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L*</td>
</tr>
<tr>
<td>Control</td>
<td>0.264±0.009</td>
<td>77.92±0.02</td>
<td>77.92±0.02</td>
<td>84.33±0.78</td>
</tr>
<tr>
<td>Chi 2</td>
<td>0.232±0.002</td>
<td>53.81±0.03</td>
<td>53.81±0.03</td>
<td>47.59±0.19</td>
</tr>
<tr>
<td>Par 2</td>
<td>0.231±0.001</td>
<td>52.95±0.01</td>
<td>13.62±0.02</td>
<td>50.71±1.19</td>
</tr>
<tr>
<td>Cor2</td>
<td>0.209±0.002</td>
<td>27.35±0.02</td>
<td>21.4±0.05</td>
<td>48.37±0.02</td>
</tr>
<tr>
<td>Dil 2</td>
<td>0.184±0.003</td>
<td>41.62±0.01</td>
<td>20.4±0.03</td>
<td>51.30±0.32</td>
</tr>
<tr>
<td>Roc2</td>
<td>0.364±0.005</td>
<td>26.16±0.05</td>
<td>24.98±0.01</td>
<td>52.48±0.08</td>
</tr>
</tbody>
</table>

In which, Control: cracker with %100 wheat flour. Chi 2: cracker with 10% chicory powder. Par 2: cracker with 10% parsley powder. Cor2: cracker with 10% coriander powder. Dil 2: cracker with 10% dill powder. Roc2: cracker with 10% rocket powder.

Table 7. Total phenolic, Total Flavonoids, chlorophyll a and b, Total carotenoids content and Antioxidant activity of crackers enrichment with green leafy vegetable powder.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total phenolic content (mg/100g)</th>
<th>Total Flavonoids (mg/100g)</th>
<th>Chl. a (mg/g)</th>
<th>Chl. b (mg/g)</th>
<th>Total Carotenoids (mg/g)</th>
<th>Antioxidant activity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>33.38±3.12</td>
<td>19.1±1.95</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>6.43±0.15</td>
</tr>
<tr>
<td>Chi 2</td>
<td>72.81±2.19</td>
<td>67.5±2.10</td>
<td>0.215±0.001</td>
<td>0.289±0.002</td>
<td>0.139±0.002</td>
<td>37.88±0.26</td>
</tr>
<tr>
<td>Par 2</td>
<td>66.67±1.84</td>
<td>20.7±1.80</td>
<td>0.282±0.003</td>
<td>0.300±0.001</td>
<td>0.157±0.003</td>
<td>37.76±1.26</td>
</tr>
<tr>
<td>Cor 2</td>
<td>61.99±1.12</td>
<td>23.5±1.85</td>
<td>0.263±0.002</td>
<td>0.465±0.003</td>
<td>0.169±0.001</td>
<td>31.62±2.33</td>
</tr>
<tr>
<td>Dil 2</td>
<td>73.06±1.63</td>
<td>39.1±1.85</td>
<td>0.184±0.002</td>
<td>0.106±0.011</td>
<td>0.110±0.003</td>
<td>38.64±1.85</td>
</tr>
<tr>
<td>Roc 2</td>
<td>71.52±0.99</td>
<td>55.7±1.90</td>
<td>0.474±0.001</td>
<td>0.410±0.001</td>
<td>0.135±0.001</td>
<td>37.33±1.73</td>
</tr>
</tbody>
</table>

In which, Control: cracker with %100 wheat flour. Chi 2: cracker with 10% chicory powder. Par 2: cracker with 10% parsley powder. Cor2: cracker with 10% coriander powder. Dil 2: cracker with 10% dill powder. Roc2: cracker with 10% rocket powder. ND: non detected.

Data are presented as means ± SDM (n=3) & Means within a column with different letters are significantly different at P ≤ 0.05.
4. Conclusion
Healthy diet should include a lot of Green leafy vegetables, and their sufficient daily consumption could help prevent a lot of diseases. These leaves may help to meet our daily requirements of these and other essential nutrients, and they can form the cheapest and most readily available sources of protein (18.91-21.88%), fibers (9.05-10.05%), and ash (9.60-12.50%). Higher amounts of calcium and iron were found in dried rocket and parsley leaves (873.71 and 816.29 mg/100g) and (69.14 and 61.56 mg/100g), respectively, while zinc was higher in dried rocket and dill leaves (11.78 and 8.55 mg/100g, respectively). Crackers enrichment with green leafy vegetables powder (GLVP) could produce acceptable sensory quality attributes crackers with enrichment up to 10 % of (GLVP) with higher content of protein, fiber and mineral. Developing and consuming these value-added products can significantly improve the population’s nutritional status, particularly for those suffering from micronutrient deficiency.

References
Akonor, P. T., Nanam, T., Dziedzoave, E. S., Buckman, E., Mireku, Essel, Francis L. and Keith, Tomlins. (2016). Sensory optimization of crackers developed from high-quality cassava flour, starch, and prawn powder. Food science and Nutrition. 1-6
Deepali Mohite and Roji Waghmare (2020). The Fortification of Biscuits with Coriander Leaf Powder and its Effect on Physico-Chemical, Antioxidant, Nutritional and Organoleptic


