Buckwheat food factory of the future may offer products with inhibitory activity against formation of advanced glycation end-products

Henryk Zielinski¹, Małgorzata Przygodzka¹, Dorota Szawara-Nowak¹, Danuta Zielinska²

¹Department of Chemistry and Biodynamics of Food, Institute of Animal Reproduction and Food Research of the Polish Academy of Sciences, 10-748 Olsztyn, Poland

²Department of Chemistry, University of Warmia and Mazury in Olsztyn, Plac Lodzki 4, 10-727 Olsztyn, Poland
INTRODUCTION
Advanced glycation endproducts (AGEs) are produced in the advanced stage of nonenzymatic reaction between reducing sugars and amino groups, when the group of intermediate compounds produced during Amadori rearrangements react with amino groups either oxidatively or non-oxidatively. AGEs formation is a comprehensive result of amine blockage by the oxidative degradation products of sugar or lipid.

In addition to dietary sources where they are generated during food processing and storage, AGEs would also form and accumulate \textit{in vivo} via sugar-protein interactions and cause pathogenic consequences such as diabetic complications.
The initial reaction between glucose and protein amino groups forms a reversible Schiff base that rearranges to a ketoamine or Amadori product. With time, these Amadori products form AGEs via dicarbonyl intermediates such as 3-DG.
Autoxidative glycation where glucose is converted to a dicarbonyl ketoaldehyde via its enediol radical. This ketoaldehyde can react with a protein amino group to form a ketoimine capable of forming AGEs. These steps are catalysed by transition metals (M) and the superoxide radical generated can be converted to the hydroxyl radical via the Fenton reaction.
Chemical structure of (a) fluorescent cross-linking AGEs such as pentosidine and crossline, (b) non-fluorescent cross-linking AGEs such as imidazolium dilylserine cross-links, alkyl formyl glycosyl pyrrolye and arginine-lysine imidazole cross-links, (c) non-cross-linking AGEs such as pyrraline and N-carboxymethyllysine.
Medical consequences of protein glycation

Enhanced formation and accumulation of AGEs have been implicated as a major pathogenesis process leading to diabetic complications, normal aging, atherosclerosis, and Alzheimer’s Disease.
Studies for discovering and characterizing effective AGEs-inhibitors are valuable in exploring therapeutic approaches for treating AGEs associated diseases

AGEs inhibitory mechanisms

- Blocking sugar attachment
- Scavenging reactive radicals and carbonyls from lipid or sugar oxidation
- Breaking sugar-protein cross-links
AGEs-inhibitors

Synthetic

Aminoguanidine

Metformin
Carnosine
Tenilsetam
Aspirin
Vitamin B1 and B6 derivatives

Natural

**Phenolic acid and flavonoids:**
Caffeic acid
Chlorogenic acid
Epigallocatechin
Flavone C-glucosides
Quercitin
Rutin

**Food rich in polyphenols:**
Green tea
Tea infused with selected herbs
 Tomato paste
Spices
Buckwheat in Europe

- Poland
- Germany
- Italy
- Austria
- Bialorus
- Ukraine
- Sweden
- Russia
- Finland
- Norway

- Regions of cultivation and research on buckwheat
- Regions of temporary buckwheat cultivation
- Regions of buckwheat cultivation in the past
BUCKWHEAT INDUSTRY IN POLAND

Raw buckwheat → Steaming → Roasting → Dehulling → Roasted groat → Milling → Novel buckwheat flour from roasted groats

Typical milling products from unhusked and husked buckwheat:

- Hulls – waste byproduct

Wholegrain buckwheat flour

Flour from husked buckwheat
Use of buckwheat

USA
- Processed flour
  - Bread
  - Pasta products
  - Breakfast cereals

Japan
- Whole grains
  - Milled groats
    - Soba noodles
    - Extruded cereals
    - Snack products

Central-Eastern Europe
- Dehulled seeds
  - Roasted groat
    - (kasha)


Euro-ibra 2015
10th – 12th December 2015
National Museum of Natural History, Luxembourg
Buckwheat food factory of the future – waste-free and energy saving

- Selection of buckwheat cultivar
- Selection of high antioxidant material from aerial parts
- Buckwheat flowers as ingredient in healthy food products
- Buckwheat hull tea
- Patent fuel
- HP – shorter cooking time
- Gluten-free bread
- Buckwheat enriched wheat bread
- Ginger cakes enriched in rutin
- Bakery products
Biologically active compounds of buckwheat with beneficial action on consumer’s organism

- Proteins
- Phytosterols

  - Cholesterol-lowering effect
  - Improving the immunological status
  - Utilized in the treatment of type II diabetes

- Phytosterols

  - Fagopirins
  - D-chiro-inositol

- Thiamin-binding proteins

- Proteins extract

- Beneficial in treatment of the hypertension, obesity, alcoholism, constipation

- Flavonoids

- Utilized for people who suffer from the lack of thiamin and can not store thiamin
Buckwheat phytochemicals attracting attention due to their potential health beneficial action

<table>
<thead>
<tr>
<th>Buckwheat flavonoids</th>
<th>R₁</th>
<th>R₂</th>
<th>R₃</th>
<th>R₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>rutin</td>
<td>OH</td>
<td>rutinose</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>quercetin</td>
<td>OH</td>
<td>OH</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>quercitrin</td>
<td>OH</td>
<td>ramnose</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>orientin</td>
<td>OH</td>
<td>H</td>
<td>H</td>
<td>glucose</td>
</tr>
<tr>
<td>homoorientin</td>
<td>OH</td>
<td>H</td>
<td>glucose</td>
<td>H</td>
</tr>
<tr>
<td>vitexin</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>glucose</td>
</tr>
<tr>
<td>isovitexin</td>
<td>H</td>
<td>H</td>
<td>glucose</td>
<td>H</td>
</tr>
</tbody>
</table>
Potential health beneficial action of buckwheat flavonoids

Rutin (quercetin-3-rutinoside)
- anti-inflammatory and vasoactive properties
- capability to diminish capillary permeability
- reduce the risk of arteriosclerosis
- reducing coronary heart disease,
- diminishing of platelet aggregation
- inhibiting low-density lipoprotein (LDL) peroxidation
- protective effects against ethanol-induced gastric lesions
- against DNA damage
- protective agent against carcinogenesis
- **the most potent natural inhibitors of AGEs formation**
- hypocholesterolemic effect in humans after the intake of buckwheat products.

Orientin
Homoorientin
Isovitexin
Vitexin
- hypotensive properties
- anti-inflammatory
- antispasmodic
- antimicrobial
- radioprotective effects
- anti-glycation activity
Absorption mechanism is recognized

GLYCOSIDES - absorption starts from the colon
limitations – can be substantially degraded by local microflora
Degradation of rutin in the colon

3-Hydroxyphenylacetic acid

3,4-Dihydroxyphenylacetic acid

Homovanillic acid

3,4-Dihydroxytoluene

THE AIM OF THE STUDY

To find out the potential non-pharmacologic prevention of buckwheat enhanced products against formation of advanced glycation end products (AGEs) due to the presence of quercetin-3-O-rutinoside (rutin) – the main buckwheat flavonoid and other polyphenol sources.
MATERIAL

PART I. BUCKWHEAT ENHANCED WHEAT BREADS

PART II. RYE-BUCKWHEAT GINGER CAKES ENRICHED WITH RUTIN

PART III. INNOVATIVE BREADS ENHANCED WITH NATURAL INGREDIENTS CONTAINING POLYPHENOLS

PART IV. BITTER BUCKWHEAT TEA FROM UNHUSKED TARTARY BUCKWHEAT

PART V. BUCKWHEAT HULL TEA INFUSION
PART I. BUCKWHEAT ENHANCED WHEAT BREADS

- White wheat flour type 500,
- buckwheat flour “BIO” from whole grain of common buckwheat (variety Kora),
- novel flour from roasted buckwheat groats
PART I. BUCKWHEAT ENHANCED WHEAT BREADS

- Buckwheat flour “BIO”
  - 10%
  - 20%
  - 30%
  - 40%
  - 50%

- Buckwheat flour from roasted groat
  - 10%
  - 20%
  - 30%
  - 40%
  - 50%

- White wheat flour
  - 100%
  - 90%
  - 80%
  - 70%
  - 60%
  - 50%

Reference white wheat bread
- Buckwheat enriched wheat bread (10/90)
- Buckwheat enriched wheat bread (20/80)
- Buckwheat enriched wheat bread (30/70)
- Buckwheat enriched wheat bread (40/60)
- Buckwheat enriched wheat bread (50/50)
Flour mixing
Substitution 10%, 20%, 30% and 50%

White wheat flour type 500

Buckwheat flour „BIO”

Buckwheat flour from roasted groats

Dough making

Dough making

Dough making

Cutting dough into pieces (250g)
Shaping into loaf
Dough rising at 37°C, 25min

Baking 250°C, 30min

Baking 250°C, 30min

Baking 250°C, 30min

Buckwheat enhanced white wheat breads

Reference white wheat bread

Roasted buckwheat enhanced white wheat breads

Flour, salt, yeasts and water

BUCKWHEAT ENHANCED WHEAT BREADS FORMULATION AND BAKING CONDITIONS
PART II. RYE-BUCKWHEAT GINGER CAKES ENRICHED WITH RUTIN

- Flour from husked buckwheat
- Flour from roasted buckwheat groats

**Rye-buckwheat ginger cakes with LOW addition of rutin**
(2.5 mg of rutin in 50 g of product)

**Rye-buckwheat ginger cakes with MEDIUM addition of rutin**
(12.5 mg rutin in 50 g of product)

**Rye-buckwheat ginger cakes with HIGH addition of rutin**
(25 mg rutin in 50 g of product)
FORMULATION OF RYE-BUCKWHEAT GINGER CAKES WITH RUTIN

**RYE FLOUR**
- Rye flour: 100 g

**BUCKWHEAT FLOUR**
- Flour from husked buckwheat: 30 g
- Flour from roasted buckwheat groats: 30 g

**HONEY**
- Buckwheat honey: 50 g

**SUGAR**
- Sugar: 20 g

**BUTTER**
- Butter: 25 g

**SPICE MIX**
- Spice mix: 2 g

**SYNTHETIC RUTIN**
- Synthetic rutin: 10 mg, 50 mg, 100 mg

**DOUGH MAKING**

**BAKING**
- Baking: 180 °C, 18 minutes

**CONTROL**
- Rye flour: 70 g
- Buckwheat honey: 50 g
- Sugar: 20 g
- Baking soda: 3 g
- Butter: 25 g
- Spice mix: 2 g

**Buckwheat honey 50 g**
**sugar 20 g**
**baking soda 3 g**
**butter 25 g**
**spice mix 2 g**

**Buckwheat honey 50 g**
**sugar 20 g**
**baking soda 3 g**
**butter 25 g**
**spice mix 2 g**
50 g of ginger cakes with high amount of rutin corresponds to one tablet of rutin.
PART III. INNOVATIVE BREADS ENHANCED WITH NATURAL INGREDIENTS CONTAINING POLYPHENOLS

IN-1: spelt bread with cherry (P.410947, 2015, PL),

IN-2: mixed wheat/rye bread enhanced with roasted buckwheat flour (P.411732, 2015, PL)

IN-3: mixed wheat/rye bread enriched with dry onion skins (P.411555, 2015, PL)

IN-4: sourdough fermented rye bread enriched with roasted buckwheat hull (P.411731, 2015, PL)

IN-5: roll type graham with raw buchwheat hull (P.410730, 2014, PL)
Part IV. BITTER BUCKWHEAT TEA FROM UNHU$$KED TARTARY BUCKWHEAT

2 g of tartary buckwheat groats

+ 200 mL of boiled water

bitter buckwheat tea

The bitter buckwheat tea (SOBA TEA) originated from the Yunnan province of China and was made from unhusked tartary buckwheat, while the green tea with mint was produced by R. Twinning & Co Ltd., London (England).
Part V. BUCKWHEAT HULL TEA INFUSION

2 g of buckwheat hull + 200 mL of boiled water = ready-to-drink tea
HOW DID WE PERFORM THE \textit{IN VITRO} STUDY?

MODEL SYSTEMS:

BSA + glucose

BSA + methylglyoxal

Methylglyoxal is proven to be the most important glycation agent (forming AGEs)

side-product of several metabolic pathways (intermediate of threonine catabolism, lipid peroxidation and glycolysis)
Glucose

Glycation
- Schiff base
  - Amadori products
    - Intermediary glycation products
      - Advanced Glycation End-products

Glycoxydation
- Oxydative stress
  - Glyoxal
    - Methylglyoxal...
      - Protein-NH₂
  - 3-Deoxyglucosone
    - Protein-NH₂
  - Intermediary glycation products

aminoguanidine
HOW DID WE DETERMINE AGES FORMATION/INHIBITION?

**FLUORESCENCE ANALYSIS**

- fluorescence of the solution with inhibitors
- % inhibition = \( \{1 - \frac{\text{fluorescence of the solution with inhibitors}}{\text{fluorescence of the solution without inhibitors}}\} \times 100\% \)

- aminoquinidine (AG) 1 mM was used as positive control
Measurement of the inhibitory effect of buckwheat enhanced products on the formation of advanced glycation end products (AGEs)

- **BSA-MGO**
  - Incubation (37°C; 168h)
  - Fluorescence intensity ($\lambda_{\text{EX}}$=320nm; $\lambda_{\text{EM}}$=420nm)

- **BSA-GLUCOSE**
  - Incubation (55°C; 40h)
  - Fluorescence intensity ($\lambda_{\text{EX}}$=330nm; $\lambda_{\text{EM}}$=410nm)

**BUFFER BREAD/CAKE EXTRACTS**
- (dissolved in 5mL of phosphate buffer 0,1M pH 7,4)

**EVAPORATION TO DRYNES**
- (40°C)

**BREAD/CAKE EXTRACTS**
- (1g/5mL 67% MeOH; 37°C; 1h)
Measurement of the antioxidant properties of breads

AC - Antioxidant Capacity – measured against DPPH radicals

Total phenolic compounds (TPC)

Rutin and quercetin by HPLC-MS/MS QTRAP 5500

Reducing power by cyclic voltammetry (CV) method
RESULTS
PART I. BUCKWHEAT ENHANCED WHEAT BREADS
The inhibitory effect of buckwheat enhanced wheat bread extracts on the formation of AGEs

Inhibition AGEs vs Ru  $r = 0.86$ (BIO)
Inhibition AGEs vs Ru  $r = 0.89$ (ROASTED)
PART II. RYE-BUCKWHEAT GINGER CAKES ENRICHED WITH RUTIN
Determination of rutin content

<table>
<thead>
<tr>
<th>Ru [ug/g DM]</th>
<th>Control</th>
<th>Rye-buckwheat without rutin</th>
<th>LOW amount of rutin</th>
<th>MEDIUM amount of rutin</th>
<th>HIGH amount of rutin</th>
</tr>
</thead>
<tbody>
<tr>
<td>17,62</td>
<td>44,34</td>
<td>98,19</td>
<td>467,45</td>
<td>829,79</td>
<td></td>
</tr>
</tbody>
</table>

Ginger cakes based on flour from buckwheat flour

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Ginger cakes formulated on flour from milled roasted buckwheat groats

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ru [ug/g DM]</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>17.62</td>
</tr>
<tr>
<td>rye-buckwheat without rutin</td>
<td>44.64</td>
</tr>
<tr>
<td>LOW amount of rutin</td>
<td>151.91</td>
</tr>
<tr>
<td>MEDIUM amount of rutin</td>
<td>470.13</td>
</tr>
<tr>
<td>HIGH amount of rutin</td>
<td>787.23</td>
</tr>
</tbody>
</table>
The inhibitory effect of buckwheat ginger cake extracts on the formation of AGEs

Bovine serum albumin - glucose system (BSA/glucose)

- aminoguanidine: 79.68%
- control: 26.07%
- rye-buckwheat gingercake without rutin: 33.02%
- LOW amount of rutin: 26.09%
- MEDIUM amount of rutin: 34.08%
- HIGH amount of rutin: 21.24%
-rutin: 47.62%
- ginger cakes based on flour from husked buckwheat: 36.38%
- ginger cakes formulated on flour from milled roasted buckwheat groats: 28.81%

Rutin vs BSA/Glu r = 0.47
Rutin vs BSA/Glu r = 0.93
The inhibitory effect of buckwheat ginger cake extracts on the formation of AGEs

Bovine serum albumin - methylglyoxal system (BSA/MGO)

<table>
<thead>
<tr>
<th></th>
<th>aminoguanidine</th>
<th>control</th>
<th>rye-buckwheat gingercake without rutin</th>
<th>LOW amount of rutin</th>
<th>MEDIUM amount of rutin</th>
<th>HIGH amount of rutin</th>
</tr>
</thead>
<tbody>
<tr>
<td>ginger cakes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>based on flour from husked buckwheat</td>
<td>65,94</td>
<td>58,82</td>
<td>64,85</td>
<td>62,65</td>
<td>60,48</td>
<td>63,81</td>
</tr>
<tr>
<td>ginger cakes formulated on flour from milled roasted buckwheat groats</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rutin vs BSA /MGO r = 0.22
Rutin vs BSA /MGO r = 0.96
PART III. INNOVATIVE BREADS ENHANCED WITH NATURAL INGREDIENTS CONTAINING POLYPHENOLS

IN-1: spelt bread with cherry
IN-2: mixed wheat/rye bread enhanced with roasted buckwheat flour
IN-3: mixed wheat/rye bread enriched with dry onion skins
IN-4: sourdough fermented rye bread enriched with roasted buckwheat hull
IN-5: roll type graham with raw buckwheat hull
Content of phenolic acids and flavonoids

Profile of phenolics acids determined by HPLC-MS/MS

Profile of flavonoids determined by HPLC-MS/MS

- sinapic acid
- p-coumaric acid
- m-coumaric acid
- caffeic acid
- Isoferrulic acid
- quercetin
- quercetin glycosides
- rutin
The inhibitory effect of innovative breads enhanced with natural ingredients containing polyphenols on the formation of AGEs

BSA-Glucose model system

Total phenolic compounds by Follin reagent

(phenolic acids + flavonoids) vs BSA /Glu r = 0.96

Q vs BSA /Glu r = 0.95

TPC vs BSA /Glu r = 0.96
The inhibitory effect of innovative breads enhanced with natural ingredients containing polyphenols on the formation of AGEs

BSA-MGO model system

Total phenolic compounds by Follin reagent

(phenolic acids + flavonoids) vs BSA /Glu $r = 0.89$

Q vs BSA /Glu $r = 0.89$
quercetin - Q

3,3′,4′,5,7-pentahydroxyflavon

185 – 1917 mg Q/kg WM
PART IV. BITTER BUCKWHEAT TEA FROM UNHUSKED TARTARY BUCKWHEAT
Antioxidative capacity of bitter buckwheat tea and green tea with mint

<table>
<thead>
<tr>
<th>Type of tea</th>
<th>DPPH RSA (µmol Trolox/g d.m.)</th>
<th>TPC (mg catechin/g d.m.)</th>
<th>AC (µmol Trolox/g dm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitter buckwheat tea</td>
<td>125.43 ± 0.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.20 ± 0.47&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.93 ± 0.86&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Green tea with mint</td>
<td>580.64 ± 29.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.34 ± 1.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>36.93 ± 1.39&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compound</th>
<th>Extracted by 80% MeOH</th>
<th>After boiled water infusion&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homoorientin</td>
<td>84.38 ± 0.42&lt;sup&gt;a&lt;/sup&gt;</td>
<td>110.68 ± 0.73&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Orientin</td>
<td>59.14 ± 0.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>73.94 ± 0.78&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Vitexin</td>
<td>45.86 ± 0.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>80.90 ± 1.07&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rutin</td>
<td>32855.29 ± 0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10178.90 ± 0.41&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Isovitexin</td>
<td>36.50 ± 0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.35 ± 0.30&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Quercetin</td>
<td>2792.18 ± 1.94</td>
<td>nd</td>
</tr>
<tr>
<td>Total</td>
<td>35879.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10536.77&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

(µg/g d.m.)
Antioxidant capacity

Inhibition of AGEs formation

- Green tea with mint
- Bitter buckwheat tea

Inhibition of AGE formation (%)
The bitter buckwheat tea showed lower antioxidative capacity determined with the DPPH RSA and CV assays and a lower content of total phenolic compounds than the green tea with mint.

The bitter buckwheat tea contained mainly rutin and a small quantity of quercetin and flavone C-glucosides - flavonoids important from the dietary point of view.

The unhusked tartary buckwheat may be used for tea preparation as the main single tea ingredient or as a mixed component of other tisanes.
PART V.  BUCKWHEAT HULL TEA INFUSION
Total phenolic contents (TPC) and antioxidant capacity of buckwheat hull tea and green tea

<table>
<thead>
<tr>
<th>Type of tea</th>
<th>TPC (mg catechin/g d.m.)</th>
<th>AC (μmol Trolox/g d.m.)</th>
<th>DPPH test</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buckwheat hull tea</td>
<td>3.22 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.47 ± 0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.22 ± 0.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Green tea</td>
<td>87.20 ± 2.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>530.55 ± 15.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.12 ± 3.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compound</th>
<th>Buckwheat hull (µg/g d.m.)</th>
<th>Buckwheat hull tea infusion (µg/g d.m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>homoorientin</td>
<td>7.46 ± 0.47&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.13 ± 0.39&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>orientin</td>
<td>15.13 ± 0.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.70 ± 0.65&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>vitexin</td>
<td>51.66 ± 0.82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>64.70 ± 0.84&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>rutin</td>
<td>58.46 ± 0.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>62.78 ± 0.87&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>isovitexin</td>
<td>18.87 ± 0.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.05 ± 0.21&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>quercetin</td>
<td>30.90 ± 0.91</td>
<td>nd</td>
</tr>
<tr>
<td>total</td>
<td>182.48 ± 0.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>171.36 ± 0.59&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Inhibitory effects of buckwheat hull tea and green tea on the formation of AGEs in BSA-glucose model

The buckwheat hull tea showed lower inhibitory activity against the formation of fAGEs as compared to green tea.

The results provided in this study may be important for buckwheat waste product utilization.
Extracts from buckwheat enhanced wheat breads, formulated on white wheat flour and flour from roasted buckwheat groats showed higher inhibitory effects against AGEs formation than those formulated on white wheat flour and buckwheat flour “BIO”.

Rye-buckwheat ginger cakes with high rutin addition showed the highest inhibitory activity against AGEs formation as compared to ginger cakes with low and medium rutin supplementation.

Mixed wheat/rye bread enriched with dry onion skins showed the highest inhibitory activity against AGEs formation amongs innovative breads.

The unhusked tartary buckwheat may be used for functional tea preparation as the main single tea ingredient or as a mixed component of other tisanes.

The buckwheat hull tea showed lower inhibitory activity against the formation of AGEs as compared to green tea.
CONCLUSIONS

This study showed possibility of formulation buckwheat derived bakery products and infusions with effective inhibition the formation of AGEs *in vitro*.

This further supports that buckwheat derived bakery products and infusions may be beneficial food choice for diabetics as AGEs have been implicated in the pathogenesis of various diabetic complications and other diseases.

The rich source of polyphenols such as buckwheat flours, buckwheat hull, tartary buckwheat groasts should be considered as a new ingredients in the innovative buckwheat derived products.
RESEARCH TEAM:

Henryk Zieliński - Institute of Animal Reproduction and Food Research of the Polish Academy of Sciences in Olsztyn, Poland

Dorota Szawara-Nowak - Institute of Animal Reproduction and Food Research of the Polish Academy of Sciences in Olsztyn, Poland

Małgorzata Przygodzka - Institute of Animal Reproduction and Food Research of the Polish Academy of Sciences in Olsztyn, Poland

Danuta Zielińska - University of Warmia and Mazury in Olsztyn, Poland
Much of this presentation is covered by the following publication:

THANK YOU FOR YOUR ATTENTION