Buckwheat Uncovered: Bioactive Potential and Innovative Applications in Food Processing

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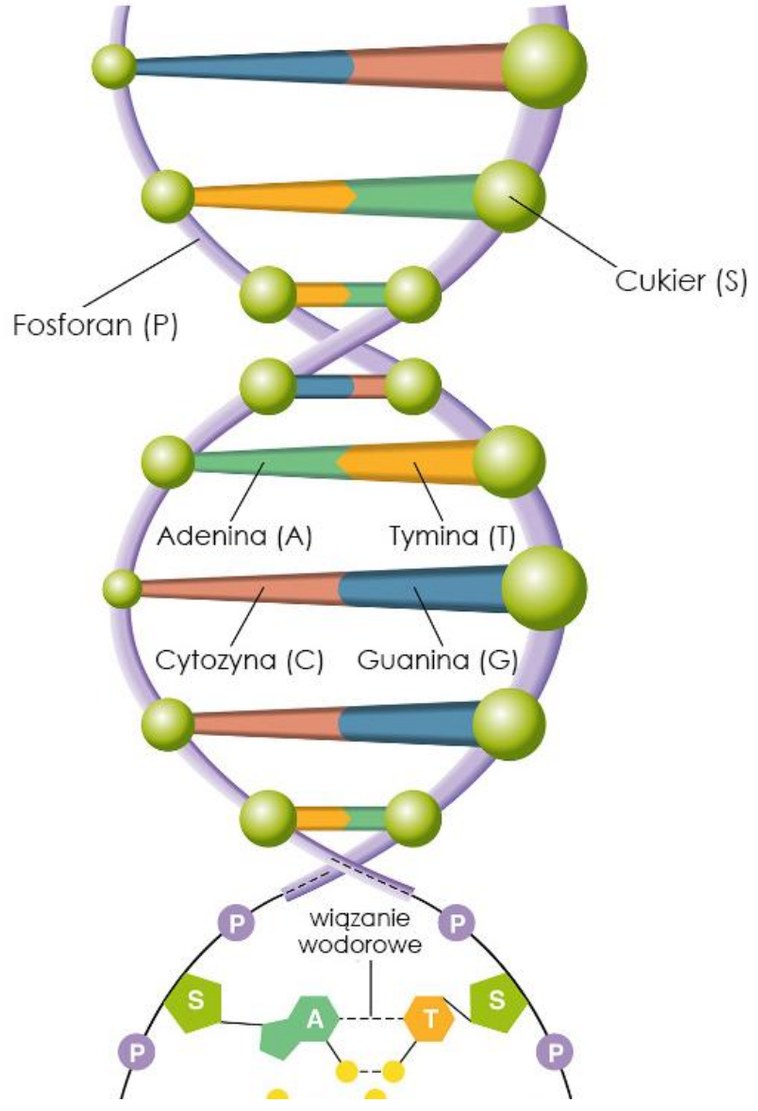
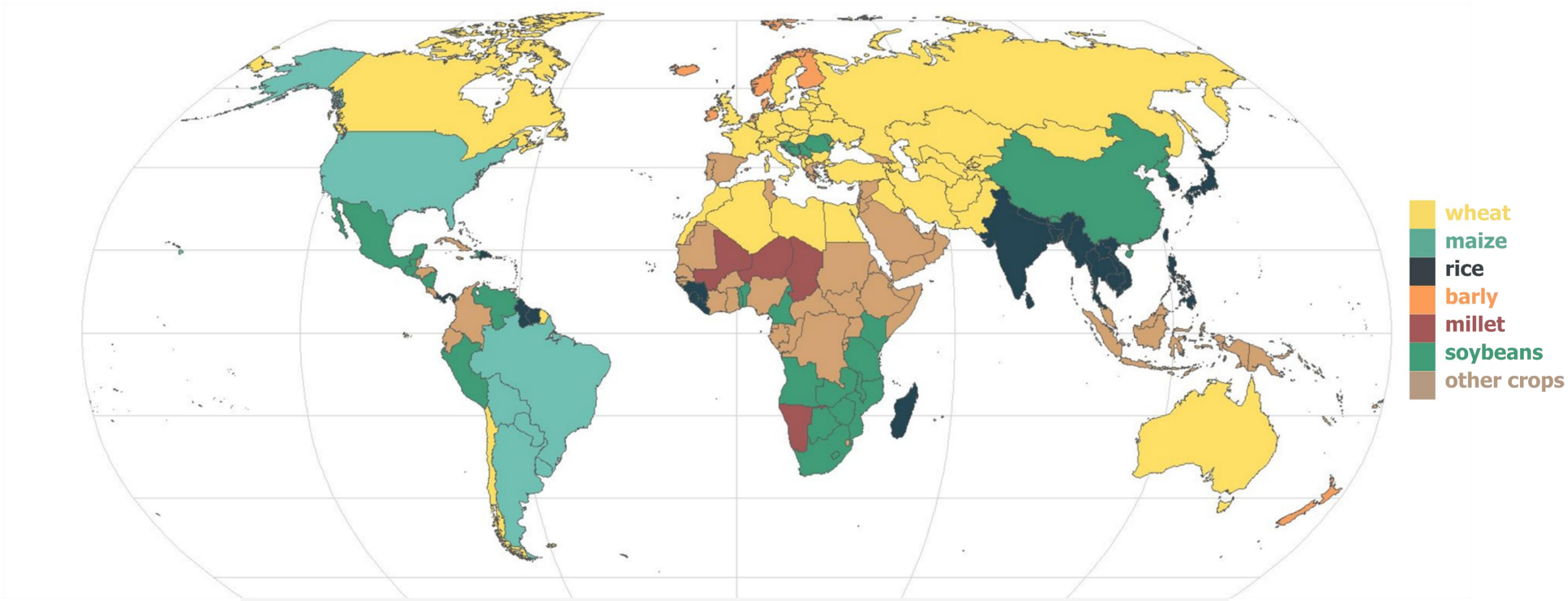
Cereals of the future

- **Plant breading and biotechnology: yield, insects and microorganism resilient, resistant for environmental changes**
- **Sustainable processing technologies: innovative and advance, World perspective (zero waste)**
- **Functional ingredient design: nutrition, sustainability, functionality, consumer acceptance**
- **Consumer-driven product innovation: sensory acceptance and physiological functions**



Future cereals

- Wheat, rice and maize???
- Buckwheat, teff, sorghum, millets, quinoa, amaranth ???
- Legum es???



FAO, 2018

Which characteristic is important?

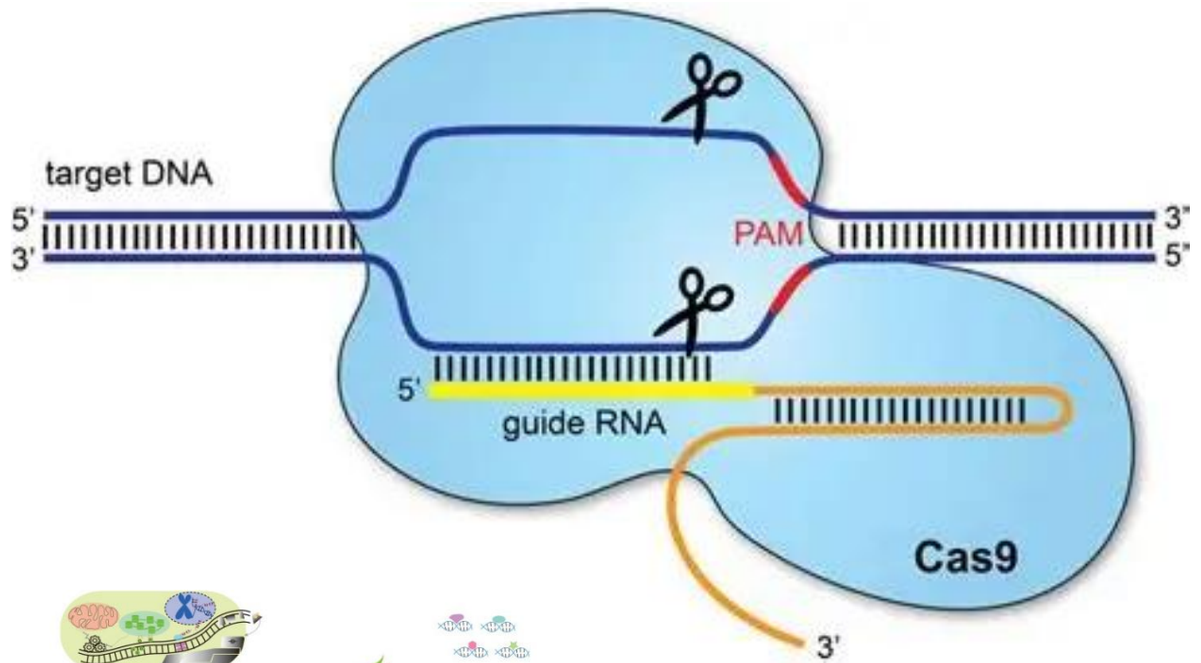
Climate resilient cereals

drought

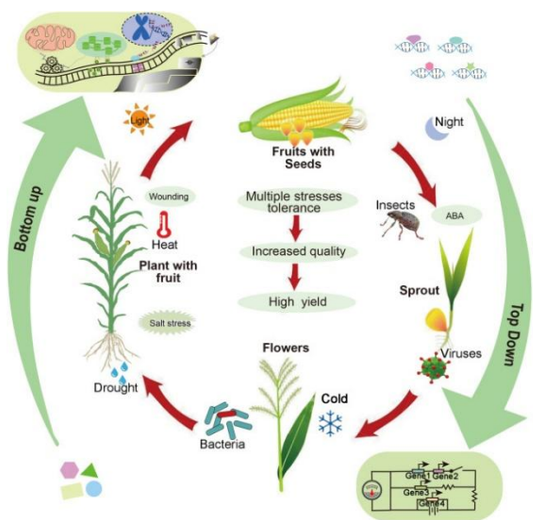
salinity

heat

Genomic-assisted breeding, CRISPR/Cas applications



Synthetic biology approaches in cereal traits design



Structure–Function–Nutrition Engineering

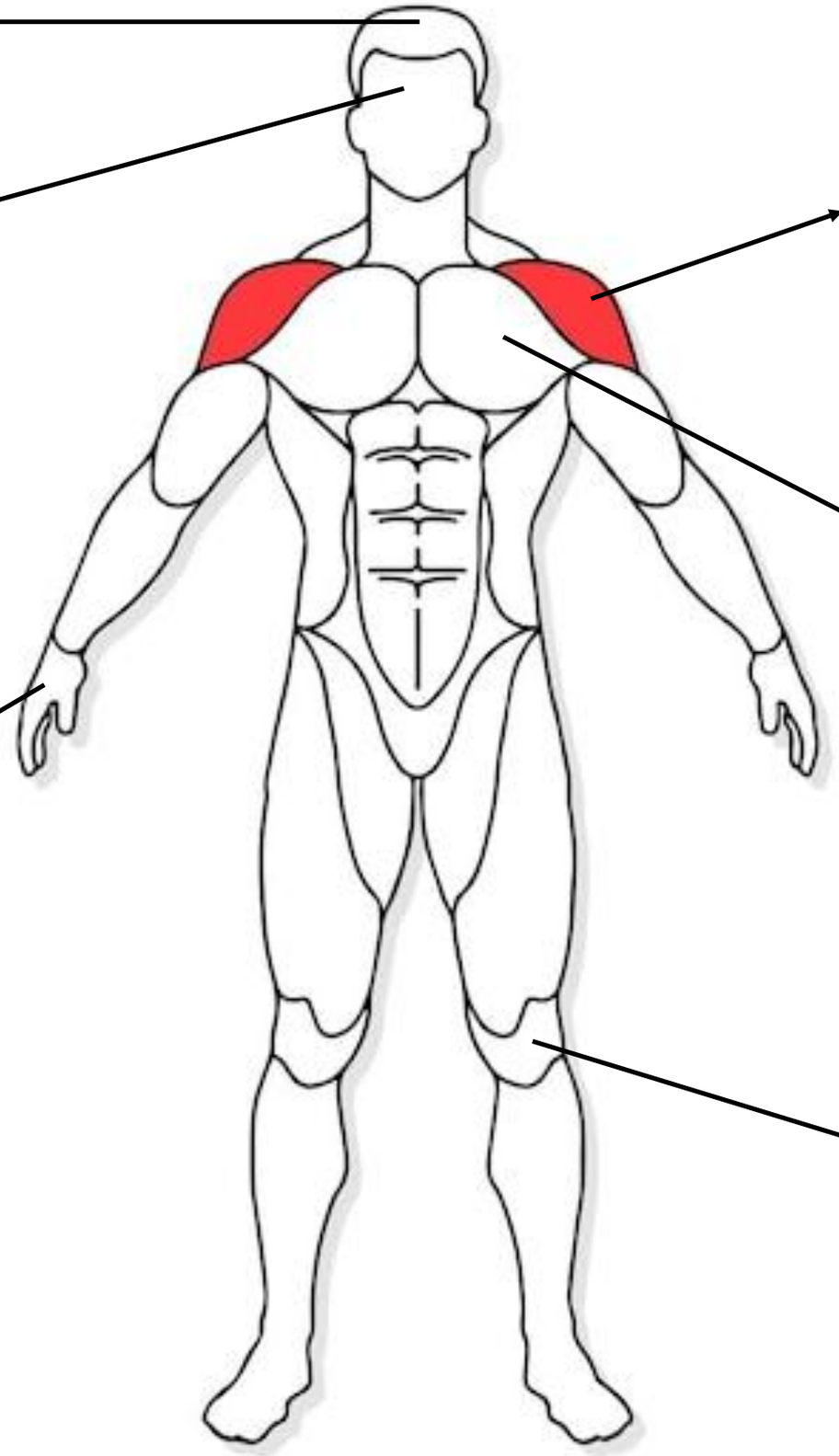
- **Protein** structuring for plant-based analogues
- **Starch** polymorphism control
- **Fiber** engineering (solubility, fermentability, gut interaction)
- **Bioavailability**
- **Glycaemic** response design
- Functional **lipids** (PUFA, omega-3)

Functional Food

HAIR
Minerals

BRAIN
Tartary
Buckwheat

SKIN
Bluberries,
salmon, green tae
Buckwheat starch



MUSSELS
Legumes,
Common
Buckwheat

HEARTS
Tartary
Buckwheat

BONES
Milk products,
meat

Kreft I., 2022

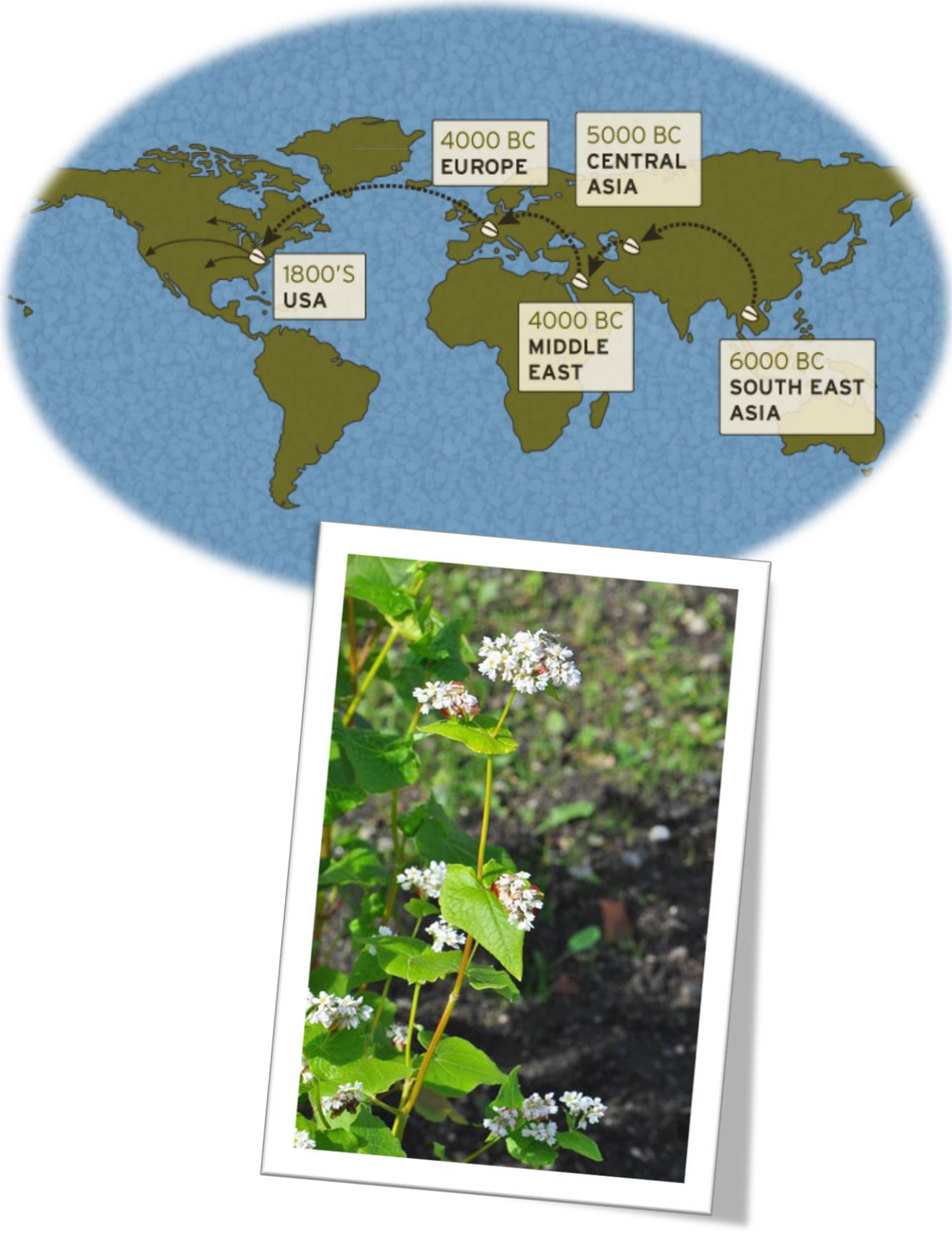
Fagopyrum esculentum Moench - cultivation history

- **Common buckwheat** was domesticated and first cultivated in Southeast Asia around 6000 BC

- spread to Central Asia, Tibet, Middle East and Europe

- documented in Europe (Finland) by at least 5300 BC

- 4000 BC: Balkans, Ukrainian, Greek and Russia



Fagopyrum esculentu

- was popular in the middle ages, but later wheat and other crops replaced it
- in Central and Eastern Europe buckwheat remained one of the major agricultural crops
- The world leader in buckwheat production: Russia and China

(FAO, 2022)

Fagopyrum tataricum Gaertn

- Wild plant- resilience for grazing animals, unfriendly environmental effect and diseases
- Not very well adapted to cultivation and harvesting
- Parts of the seeds fall down before or during harvesting and spread in the neighbour field
- Cultivated in Himalayas
- For competition with other plants founding space, soil and sunlight are not the most important

Cultivation of Common Buckwheat - benefits

Differences in the shape and structure of Common Buckwheat blossom → They do not pollinate themself → Stronger gens

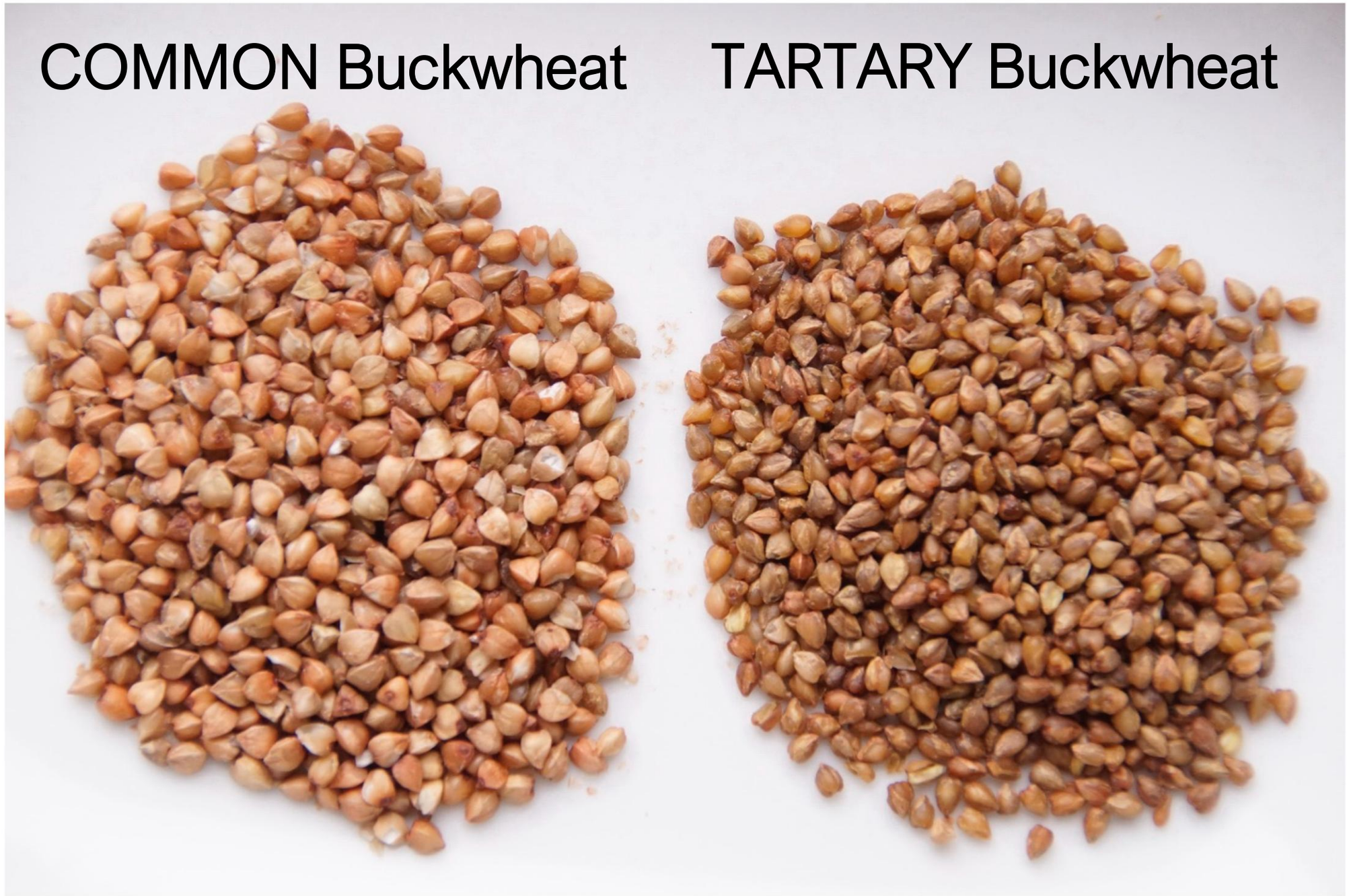
Pestecides

Not require fertilisers

Modest demand on breeding

Extensive forage resources to both honeybees

Naturally eliminates weeds



Antifungial properties: secondary metabolites with benzene rings
Aspergillus flavus

→

Rutin
Quercetin
Kaempferol

Buckwheat - composition

F. esculentum

- starch (56%)
- dietary fiber: TDF (27%), SDF (0,8%), IDF (27%)
- starch (56%, gluten - free)
- protein (12%)
- fat (3%)
- ash (2%)

F. tataricum

- starch (57%)
- dietary fiber: TDF (26%), SDF (0,5%), IDF (25%)
- starch (57%, gluten - free)
- protein (11%)
- fat (3%)
- ash (3%)

Common and Tartary Buckwheat- bioactive compounds

		Common B	Tartary B
Phenolic compounds	Total flavonoid content	▼	▲
	Secondary non-flavonoid metabolites	▼	▲▲
	Vitamin B group	▼	▲
	Health promoting value	**Lower**	**Higher**

TASTE

Phenolic compounds in buckwheat

- TPC (whole grain) 27-36 mg/g
- Flavonoids
  - **Rutin** (TBG=1.4%; CBG=0.01%)
  - **Quercitin** and its derivatives
  - **Fagopirin**

- Anthraquinone = **emodin** and its derivatives

main aktive compounds

antimacrobiological and antifungial potential

anticancer activity, anti-hypertension and anti-inflammatory action

Secondary phenolic metabolites

Rutin (Tartary buckwheat grains): 13.3 g/kg

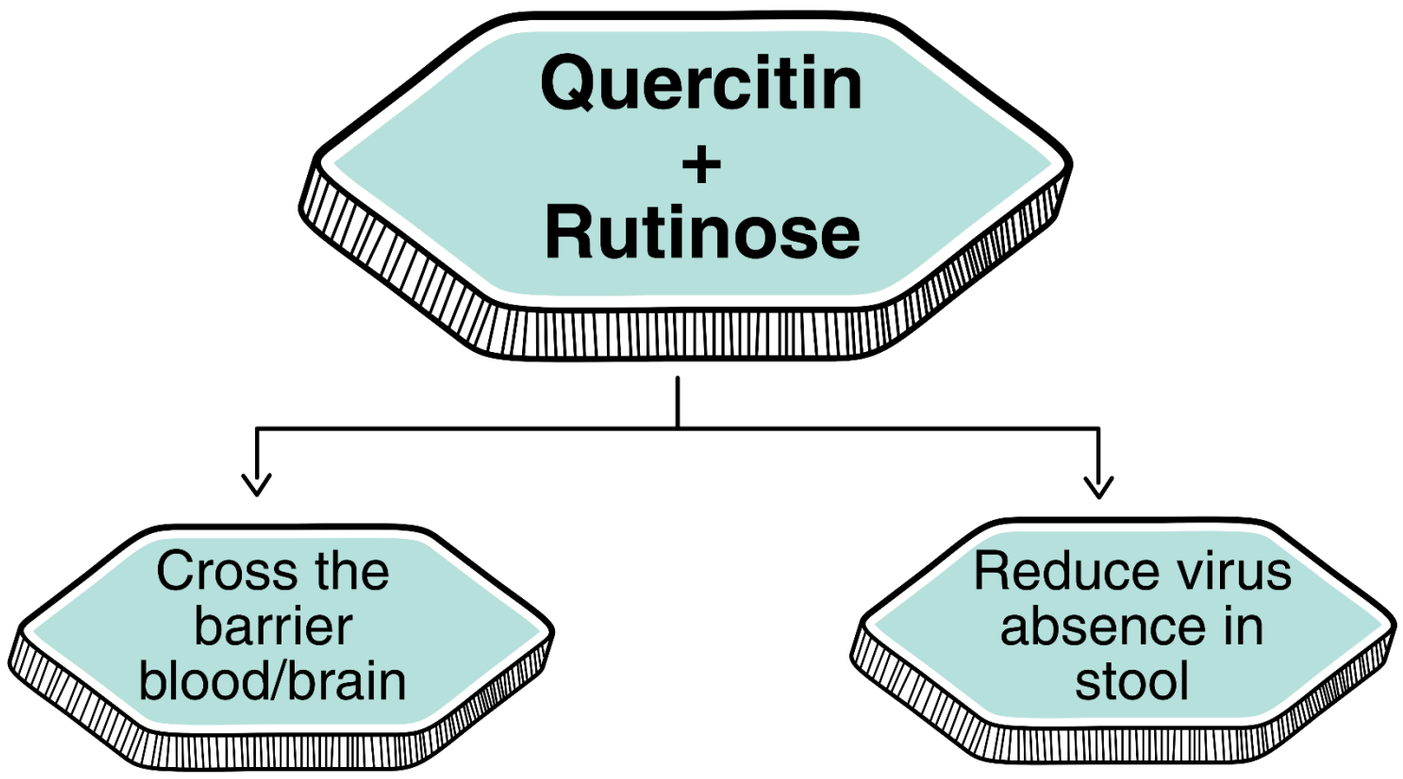
Rutin (Tartary buckwheat sprouts): 54.4 g/kg

Rutin (rutinase)

Quercetine

Protein digestion ↓

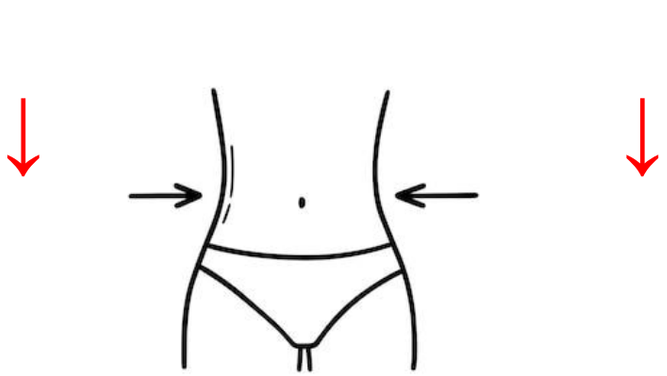
Proteins contract with microbiome

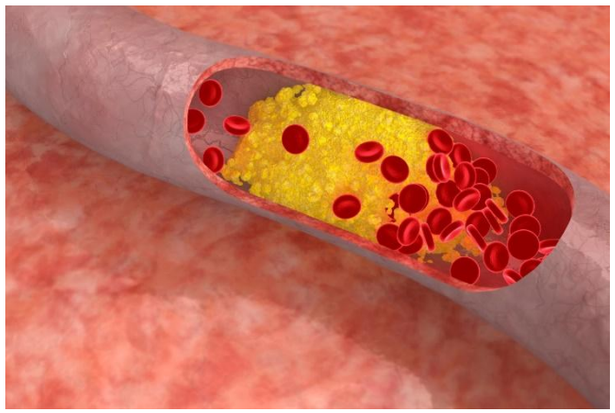


Secondary phenolic metabolites

Quercitin + starch → Resistant starch (RS)

RS = amelioration of physical properties of starch, 50% of digestibility





TAG, LDL

Tartary Buckwheat flour is not cytotoxic against cell

Secondary phenolic metabolites-extraction = **70% ethanol, few hours in room temperature**

Buckwheat proteins

Tartary Buckwheat = Common buckwheat (10-11 g/100 g)

- High essential amino acids content, mainly **lysine**:
  - Common buckwheat (6.92 and **5.84** mg/100 g of protein respectively;
  - Tartary buckwheat (7.11 and **6.18** mg/100 g of protein, respectively)

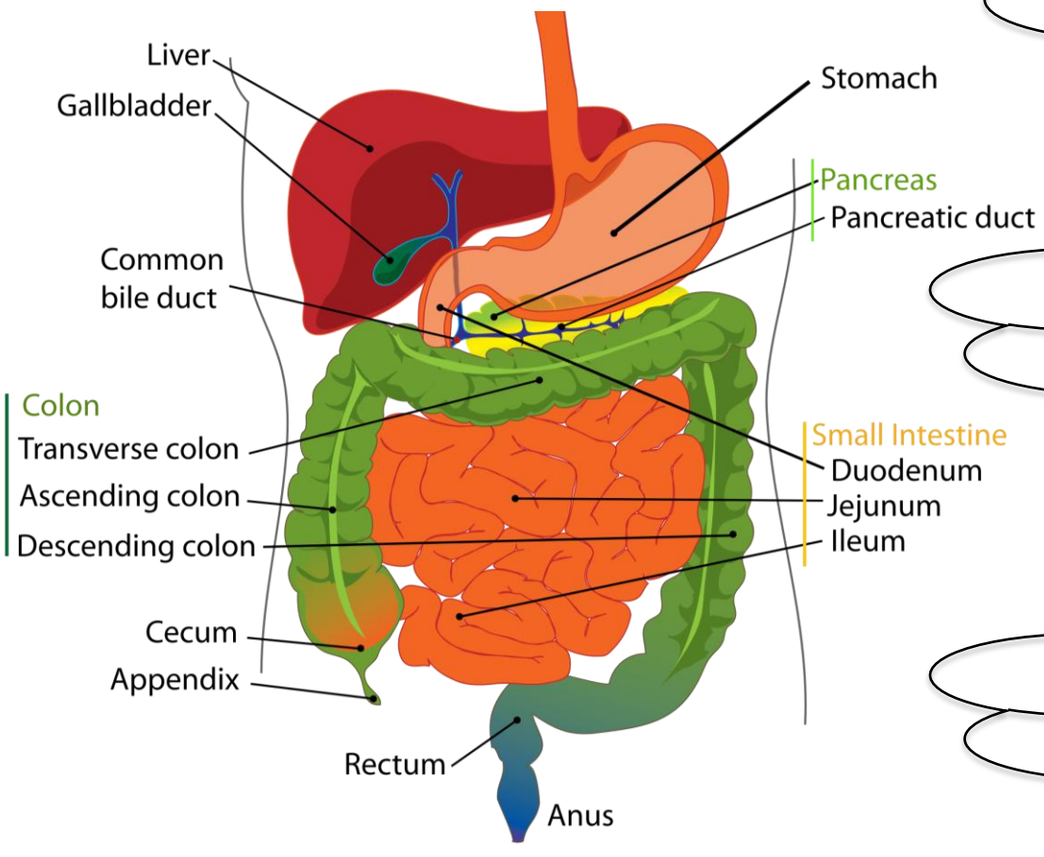
Buckwheat proteins contain selenium

Low molecular weight proteins = embryo → responsible for food alergie, however, endosperm is free of that proteins

Cultivation → bigger germ size – ↑ protein content

Buckwheat proteins

Regarding to protein-phenolic linkage
II
Proteins are resistant for digestion



proteases blocked by catechin and tannins globulin protein digestion

Nondigestible proteins: media for intestinal bacteria

Proteins bind nutritional cholesterol and bile salts

Buckwheat thermal processing: increasing bioavailability of amino acids

Proteins availability order

Soybean > Lentil > Chickpea > Pea > Quinoa > Amaranth > **Buckwheat** > Oat > Rice > Maize > Wheat > Barley

Antioxidant properties order

Buckwheat > Amaranth > Quinoa > **Soybean** > Lentil > Chickpea > Pea > Oat > Barley > Maize > Wheat > Rice

Buckwheat starch

Common buckwheat flour = 70% of starch

Thermal processing

The amylose → resistant starch

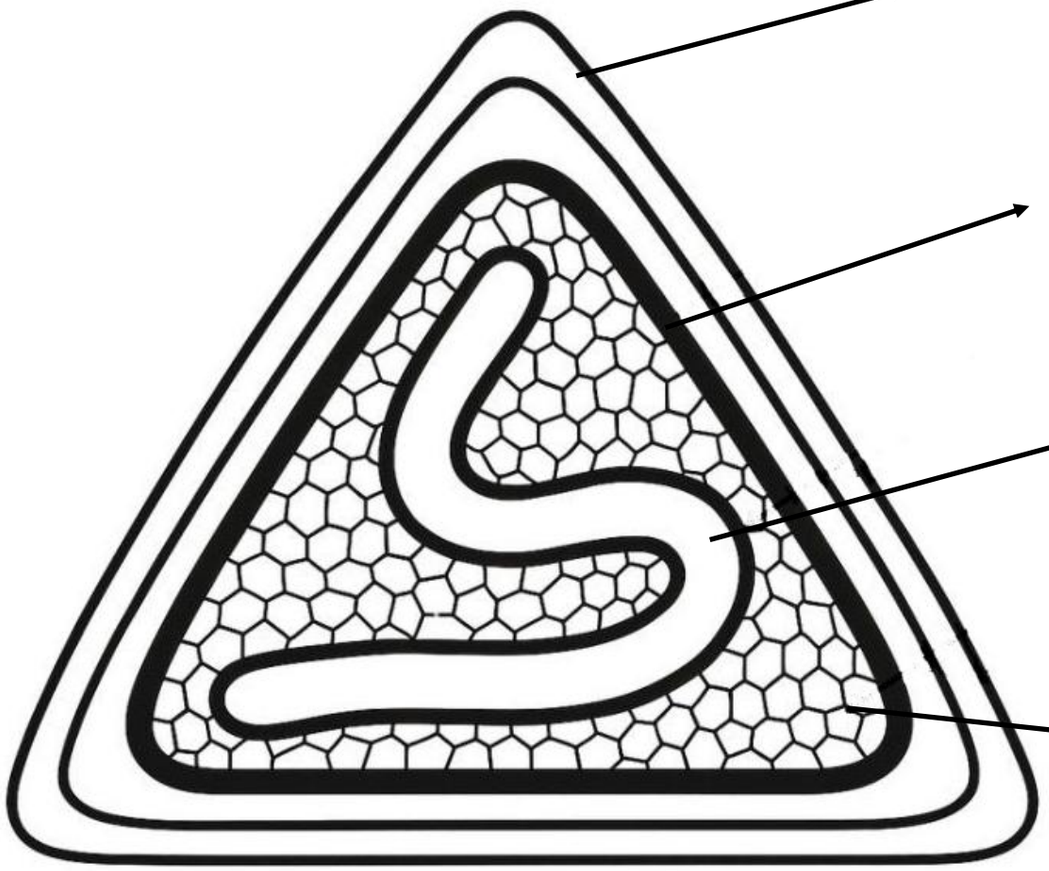
Starch granules size = small

Tartary buckwheat starch contain amylose (30%) and in addition to a high flavonoid content can be used for functional foods production

Mineral compounds

- **Buckwheat bran**
- Rb (rubidium) and Ag = **Common buckwheat**
- Se, Zn, Fe, Co, Ni, Sb, Cr, Sn = **Tartary buckwheat**
- Buckwheat leaves: infusions
- Tartary buckwheat infusions (China) can contain Zn (30-50 mg/kg), Cu (5-8 mg/kg), Cr (2.5 do 3.2 mg/kg), Ni, Pb (0.3-0.4 mg/kg) i Cd (0.5-1.2 mg/kg)
- Whole Tartary buckwheat flour (Luxemburg): Cr (0.32 mg/kg)
- **Tartary buckwheat flour (Luxemburg): Cr (0.1 mg/kg)**

Processing of grains



Hull (by-product)

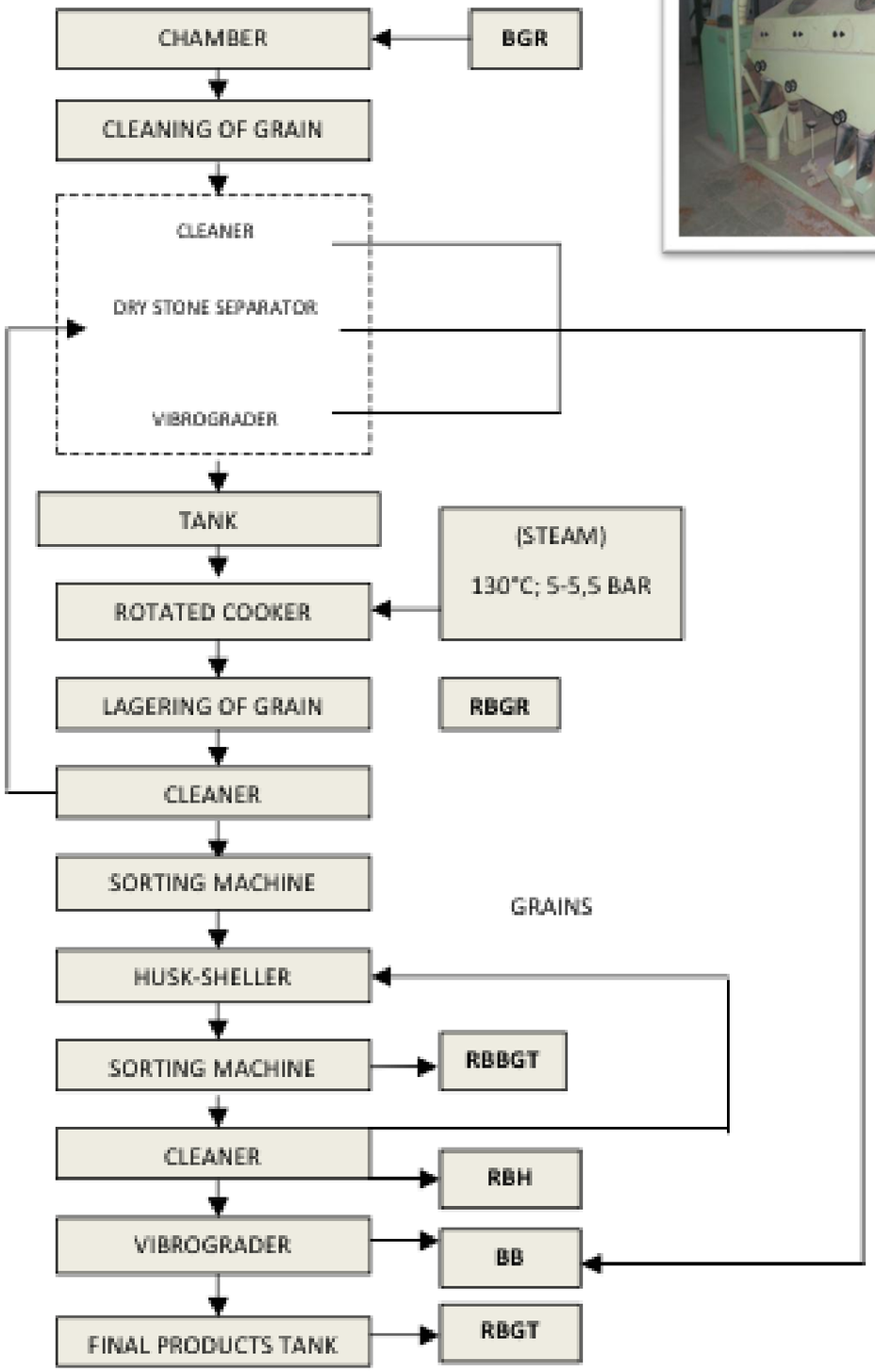
Aleurone layer (by-product)

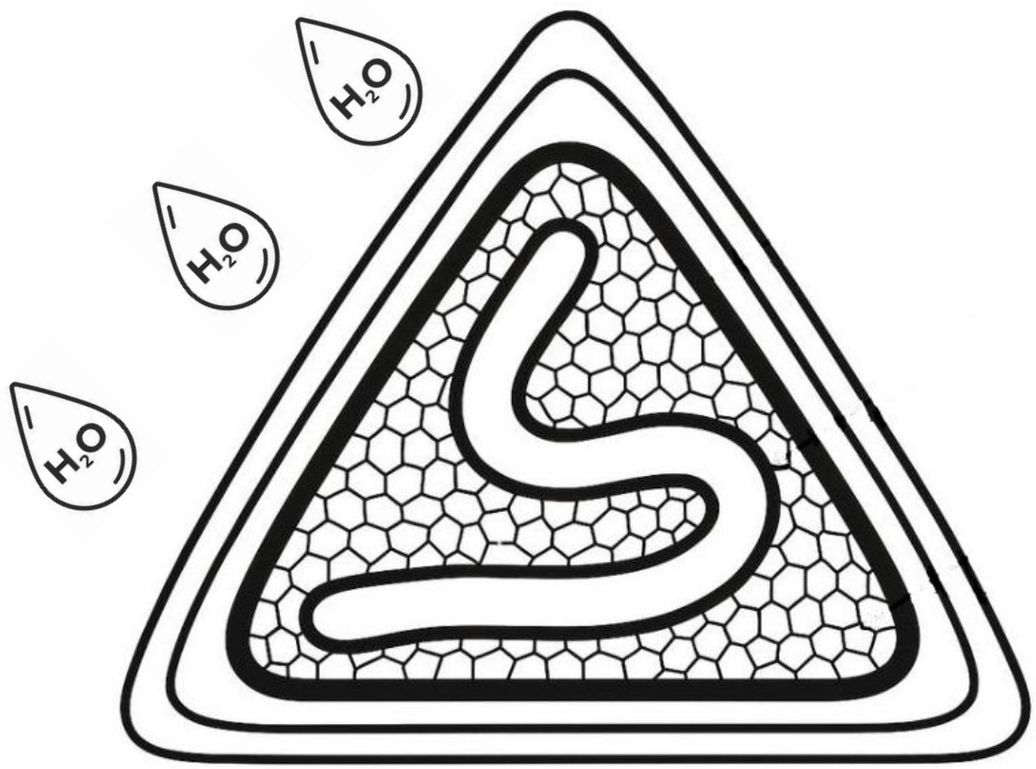
Germ contains around 4% of flavonoids, flour technological processing can be modified due to flavonoids enriched fractions (7.1% flavonoids)

Endosperm

- Fractions obtained from grinding contain mainly endosperm with 1.5% of flavonoid content, and constitute 58% of whole grain mass
- **By-products** after grinding: enriched on starch, dietary fiber and flavonoids are promising material for making foods with designed pro-healthy activity

Buckwheat groats - processing

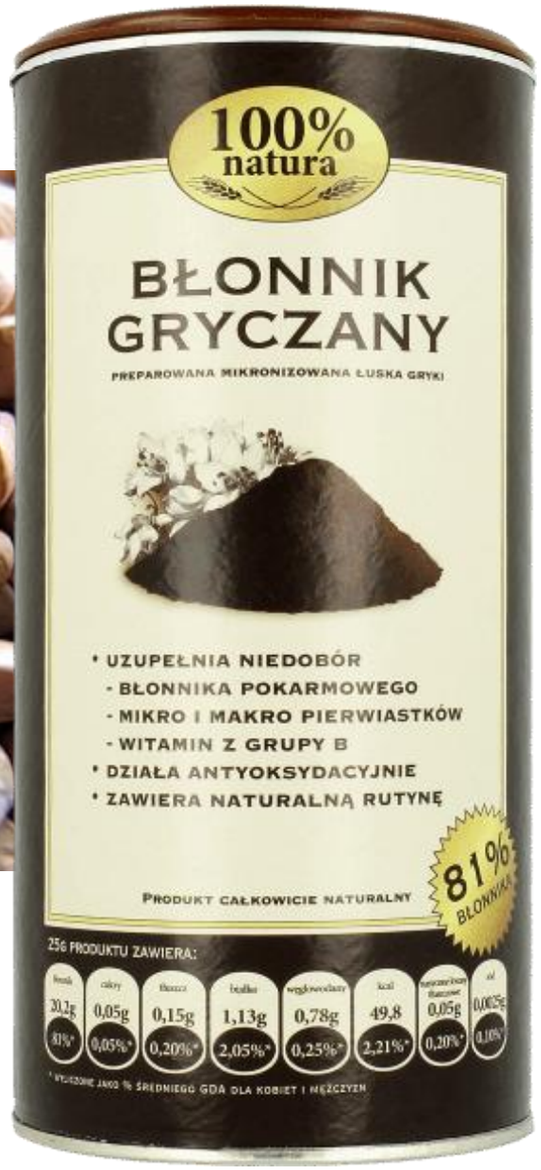




BBI

BBII

BH



BGS

Processing of buckwheat groats generates a lot of waste and by-products such as: broken buckwheat grots, buckwheat bran and buckwheat hull

Buckwheat flour

Intact starch, not easily damaged during grinding

Water-repelent starch

White flour < **Dark flour**

Proteins, DF, secondary metabolites, mineral substances

Bonafaccia et al., 2013

Common Buckwheat bread - processing

Dark flour bread > **White flour bread** Taste

Authenticity = remains of husk

~~enzymes~~

Boiled water + Buckwheat flour — Optimal quality

Wheat flour (850) + water and yeast → Rise 30’ → Placed and rise 30’

Tartary Buckwheat bread - processing

Tartary flour + Wheat flour + Rye flour = TASTE

Tartary Buckwheat sourdough bread

Wheat flour + Tartary flour + Rye flour = TASTE

Tartary Buckwheat sourdough bread – gluten free

Colorful bread made of tartary buckwheat, common buckwheat and wheat flour

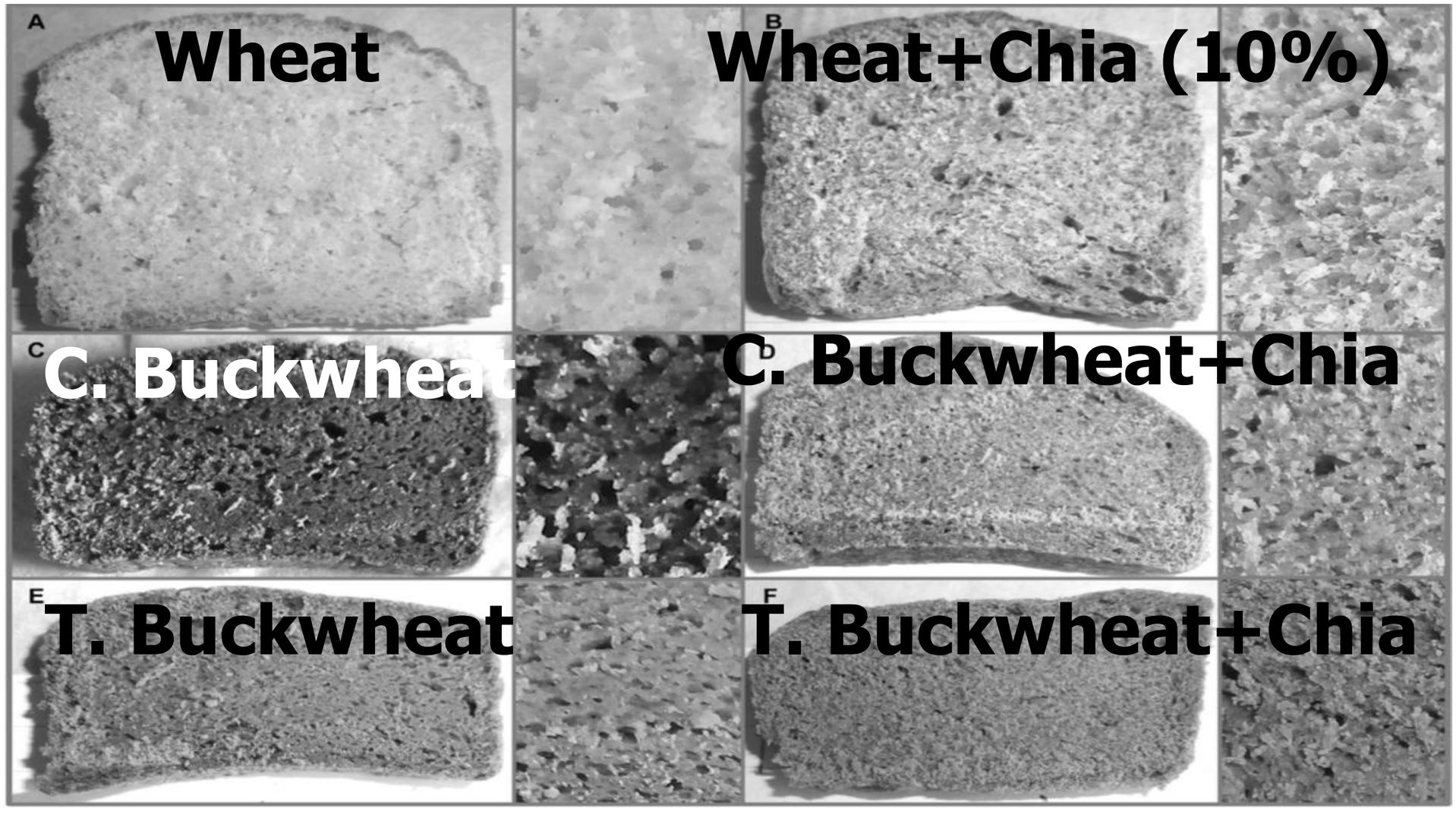
Sweet bread from milk yeast dough (tartary buckwheat)

Buckwheat products - bread

	Wheat	Common Buckwheat	Tartary Buckwheat
Moisture (%)	30.1^{c}	**40.2^{a}**	38.6^{b}
Carbohydrates (%)	**81.1^{a}**	73.2^{b}	71.5^{c}
Proteins (%)	11.10^{c}	12.90^{b}	**13.76^{a}**
Lpids (%)	1.59^{c}	3.20^{b}	**3.42^{a}**
TDF (%)	4.2^{b}	**7.4^{a}**	**7.4^{a}**
SDF (%)	1.30^{b}	**1.40^{b}**	1.00^{a}
IDF (%)	2.91^{b}	**6.00^{a}**	**6.40^{a}**
Ash (%)	2.01^{c}	3.30^{b}	**3.89^{a}**
Energie (kcal/100 g)	**270**	229	236

Buckwheat bread

	TPC (mg GAE/g)	TFC (mg RE/g)	TAC (mM FeE/g)
Tartary B. bread	53.3	16.8	30
Common B. bread	16.5	0.6	4.3
Wheat bread	3.3	0.6	0.6



Buckwheat bread

	Wheat	common buckwheat	tartary buckwheat
water absorption (%)	52.5	75	68.3
volume (mL/g)	2.7	1.4	1.34

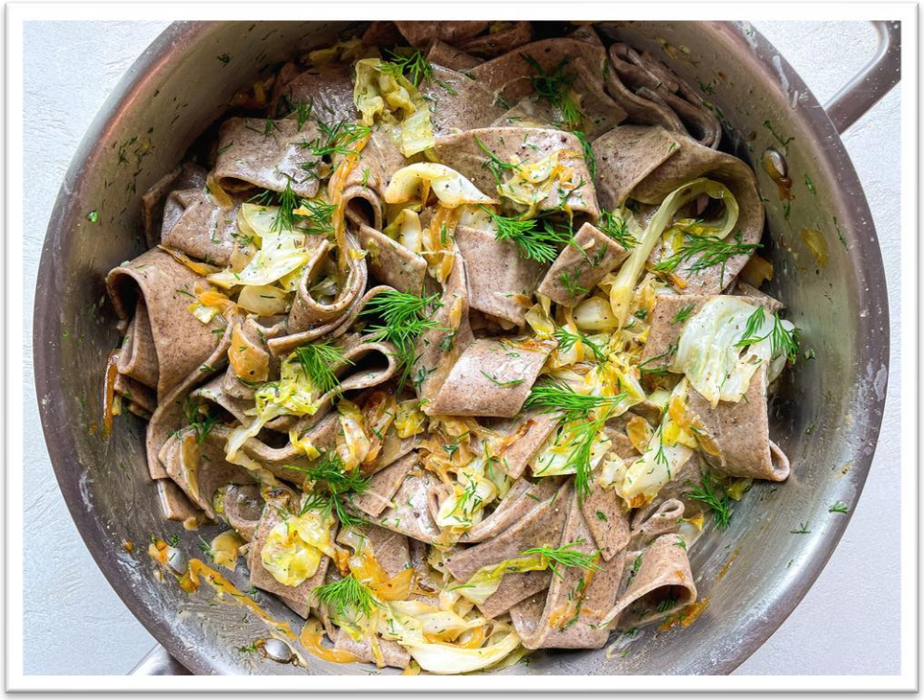
Buckwheat pasta

Buckwheat wide noodles

Buckwheat flour (75-80%)+Wheat flour

Wide: 5-10 mm
Lenth: 10 cm
Thickness: 2-3 mm

GLUTEN!!!



Buckwheat pasta

Very soft buckwheat dough (100%)

nozzles

Albumins
Globulins

Provide strength (simulation of gluten)

Rinsed in cold water 2-3 times

	Buckwheat pasta	**Wheat pasta**
Energy (kcal)	340 - 354	350 - 371
Carbohydrates (g)	70 - 78	71
Protein (g)	6 -13	11 - 13
DF (g)	4 - 5	2 - 3
Glycaemic index	61	71
Resistant starch	↑	↓
Total phenolic c.	↑	↓
Antioxidative activity	↑	↓

Buckwheat Addition on the Properties of Durum Wheat Spaghetti

↑ **Total phenolic content (TPC): 114–522%**

↑ **Total flavonoids (TFC): 50–242%**

↑ **Antioxidant activity (DPPH): >359%**

Buckwheat bran provided more phenolic and antioxidant compounds than **buckwheat flour**

Processing and cooking **reduced phenolic content and antioxidant activity**.

Cooking losses: up to **8.8%** in enriched samples vs **6.3%** in control.

SOBA: ni-hachi

Wheat flour (20%)

Buckwheat flour (80%)

Cooking and rinsing

Soba masters !

Sometimes they make pasta only from buckwheat flour

Buddhist monks eat only buckwheat noodles during long fast

SOBA: ni-hachi

(4%) >

Dough containing buckwheat bran showed better rheological properties

- **better tensile properties**
- **lower cooking loss**
- **lower enthalpy change**

Common and Tartary buckwheat

- ***F. esculentum* (CB):** very popular in Asia and eastern countries of Europe: Slovenia, Croatia, Poland, Ukraine, Belarus and Russia, in Slovenia groats are made also from TB.
- **French CB** pancakes (*galettes*) and Russian *blini* are popular the world over
- ***F. tataricum* (TB):** in last decade is increasing interest in the grain: used to make different kind of food products and dishes
- In Japan, China and Korea, **CB and TB** are used mostly to prepare noodles and other pasta products. In Italy, CB flour is used to prepare pasta, and in Slovenia and Austria, traditional dishes are CB and TB porridge. In Luxembourg, Germany, Slovenia and Italy attempts are underway to make a beer-like CB or TB drink.
- In South Korea, **TB sprouts** are a new vegetable, used for salads and smoothies. In Korea, TB is recently used for a nonalcoholic drink, in Japan, Korea and China, CB is used for strong drinks (in Japan *soba shochu*).

Fig. 1. European buckwheat dishes. (A) *Žganci*, with greaves, and served with a soup. (B) Tartary buckwheat pasta (left) and common buckwheat pasta (right). (C) *Blini*, with sour cream, and chive. (D) *Galette*, with butter, cheese, an egg and pepper.

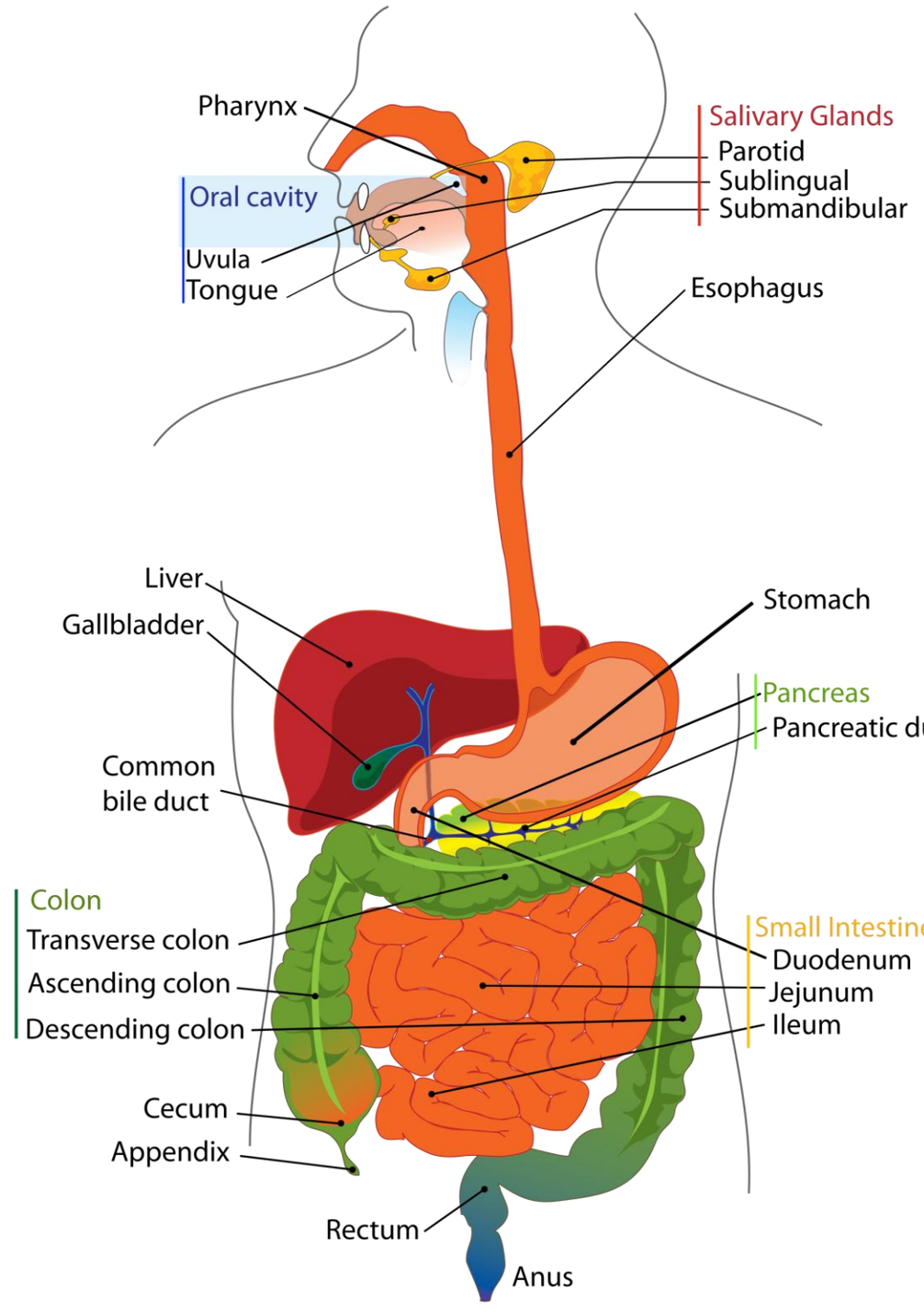
Common and Tartary buckwheat- future perspective

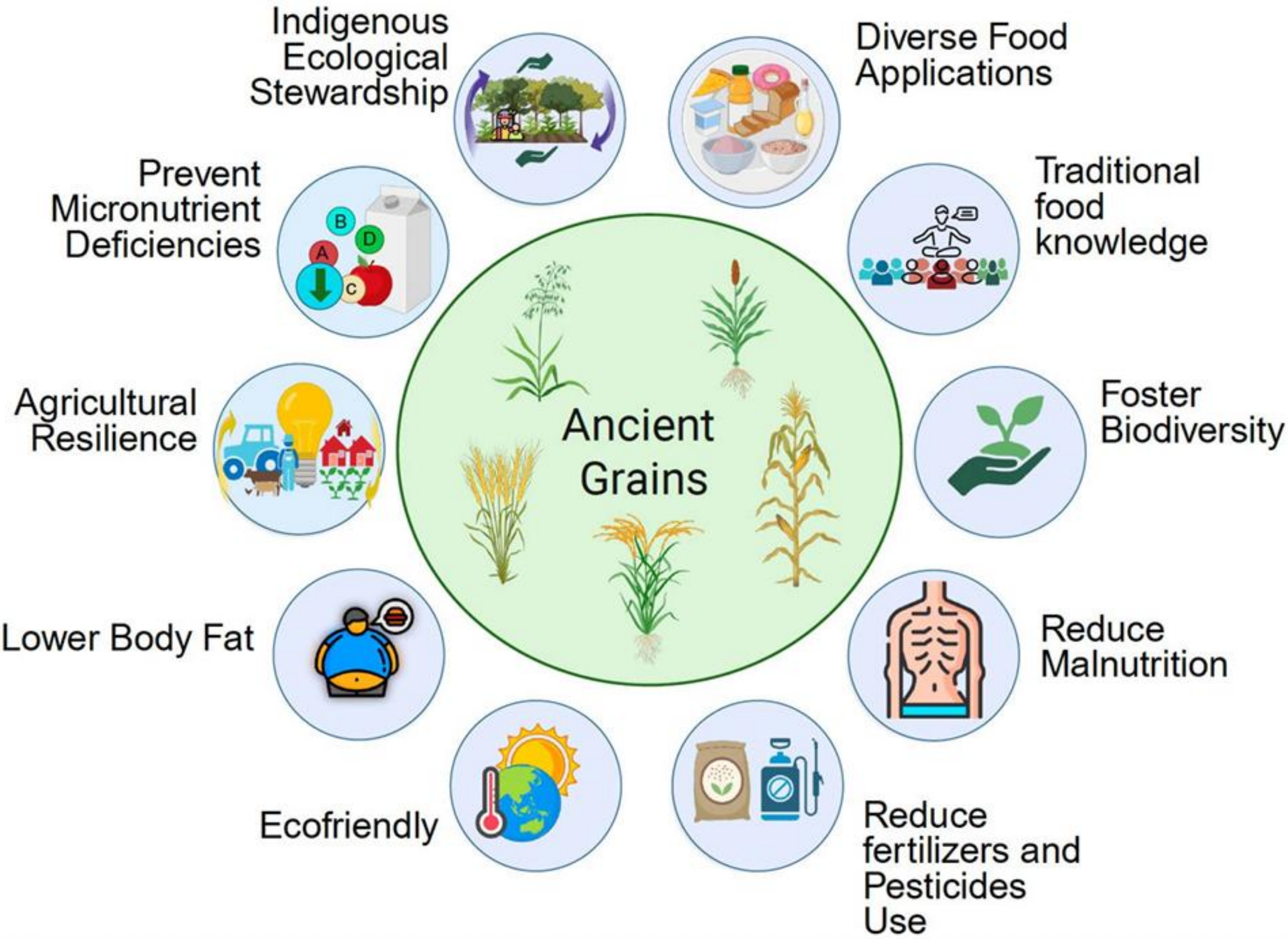
Buckwheat products - rutin content

Sample	Rutin (mg/kg)	Sample	Rutin (mg/kg)
Dark flour	218.5	Light flour	112.8
Noodles, dough	153	Buckwheat tea	204.3
Noodles, fresh	78.4	Buckwheat beer	<1
Noodles, dry	67.6	Buckwheat vinegar	<1

Buckwheat - health benefits

- reducing risk of cancer
- heart diseases (rutin and well-balanced amino acids)
- Diabetes (flavonoids and resistant starch)
- immune disorders (minerals and flavonoids)
- Binding of bile salts (dietary fiber)




Indigenous Ecological Stewardship
Diverse Food Applications
Prevent Micronutrient Deficiencies
B
D
A
C
Traditional food knowledge
Ancient Grains
Agricultural Resilience
Foster Biodiversity
Lower Body Fat
Reduce Malnutrition
Ecofriendly
Reduce fertilizers and Pesticides Use

„To cultivate and use Common or Tartary Buckwheat is a sustainable way to produce nutritious food, rich in high quality proteins, flavonoids, minerals and slowly digestible starch”

I. Kreft

References

- Dongxu Liu, Shixin Song, Li Tao a, Lei Yu, Jingyi Wang. Effects of common buckwheat bran on wheat dough properties and noodle quality compared with common buckwheat hull. LWT-Food Science and Technology. https://doi.org/10.1016/j.lwt.2021.112971.
- Yaqiong Wang, Min Tu 2, Guangyuan He, Yin Li, and Junli Chang.Toward Exploring and Utilizing the Nutritional and Functional Properties of Cereal Crops. https://doi.org/10.3390/foods12050976
- Jude Juventus Aweya, Drupat Sharma and Mohammed H. Moghadasian. Ancient Grains as Functional Foods: Integrating Traditional Knowledge with Contemporary Nutritional Science. https://doi.org/10.3390/foods14142529
- Kamila de Oliveira do Nascimento, Sany do Nascimento Dias Paes, Indianara Reis de Oliveira, Isabela Pereira Reis, Ivanilda Maria Augusta. Teff: Suitability for Different Food Applications and as a Raw Material of Gluten-free, a Literature Review. DOI:10.12691/jfnr-6-2-2.
- Kreft Ivan. Bitter seed Tartary Buckwheat. Slovenian Academia of Sciencies and arts. Ljubljana 2022.
- Kuuku Bineya, Trust Beta. Phenolic profile and carbohydrate digestibility of durum spaghetti enriched with buckwheat flour and bran. LWT-Food Science and Technology. http://dx.doi.org/10.1016/j.lwt.2014.02.033