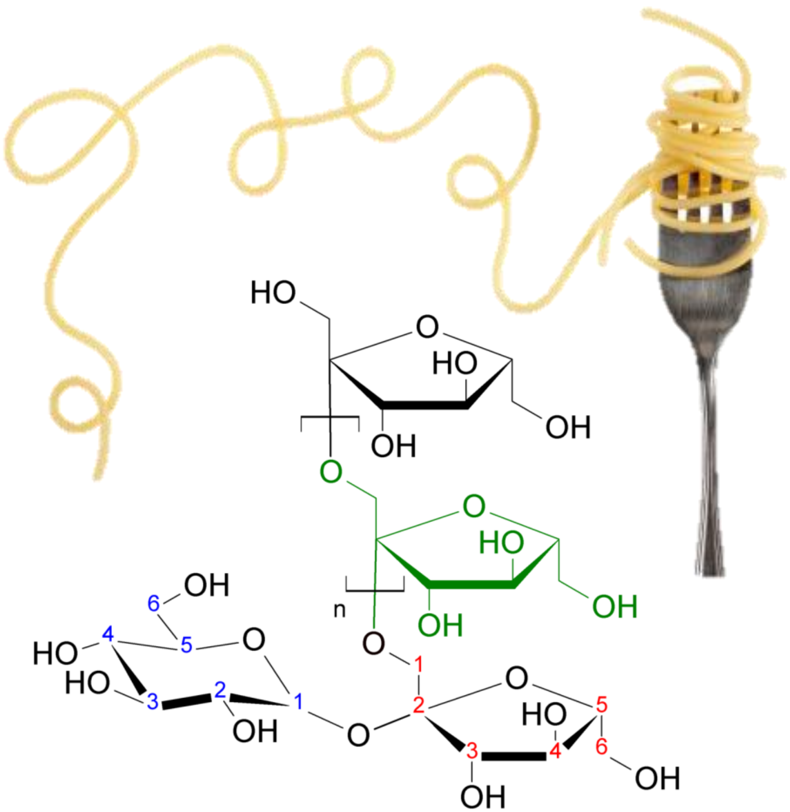
Application of inulin in pasta: The influence on technological, nutritional properties, and human health- A review



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Introduction

Inulin fructans are principally linear molecules including predominantly β-(2-1) fructosyl-fructose links and have typically a terminating glucose molecule.

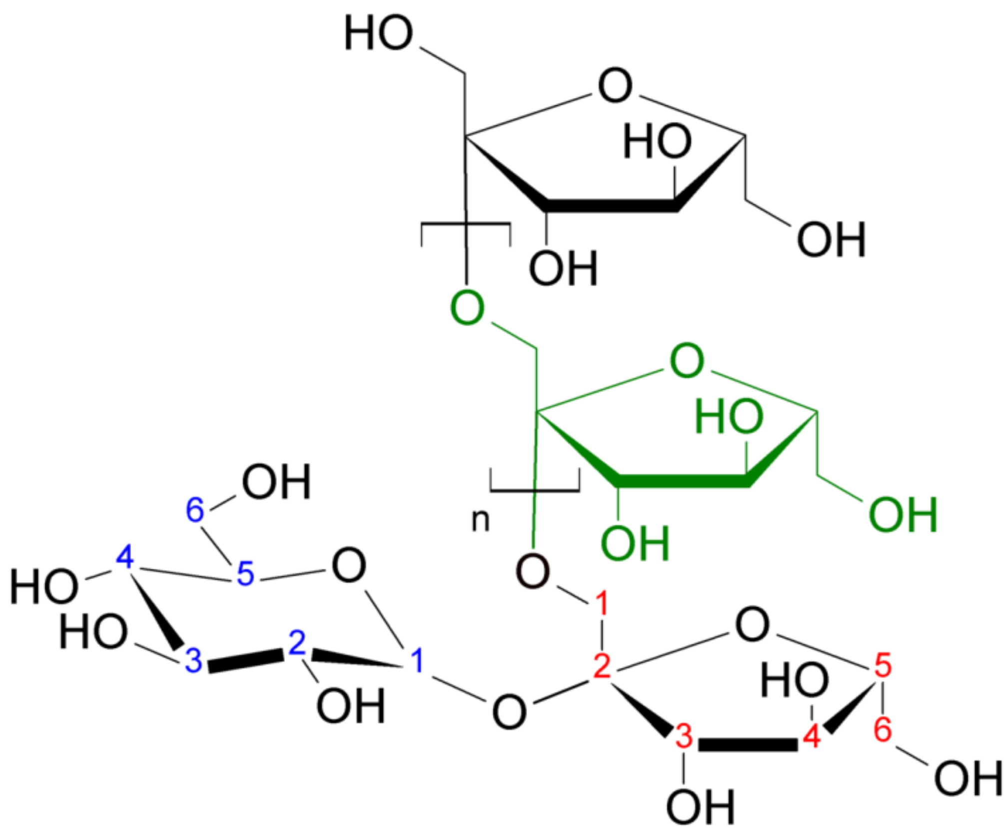

Fig. 1. The structure of inulin

Mudannayake et al., 2022

Introduction

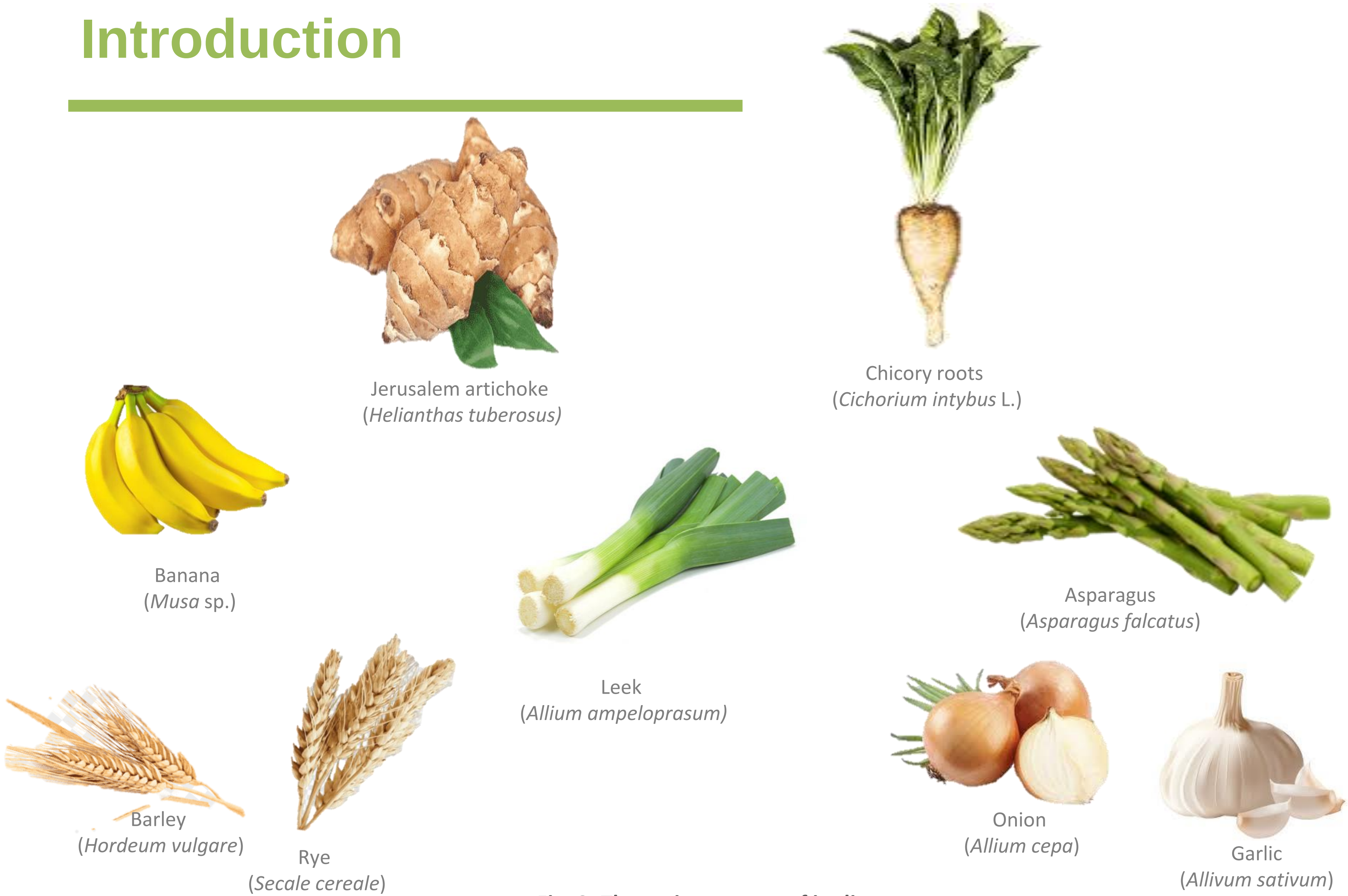

Fig. 2. The major sources of inulin

Mudannayake et al., 2022, Teferra et al. ,2021

Introduction

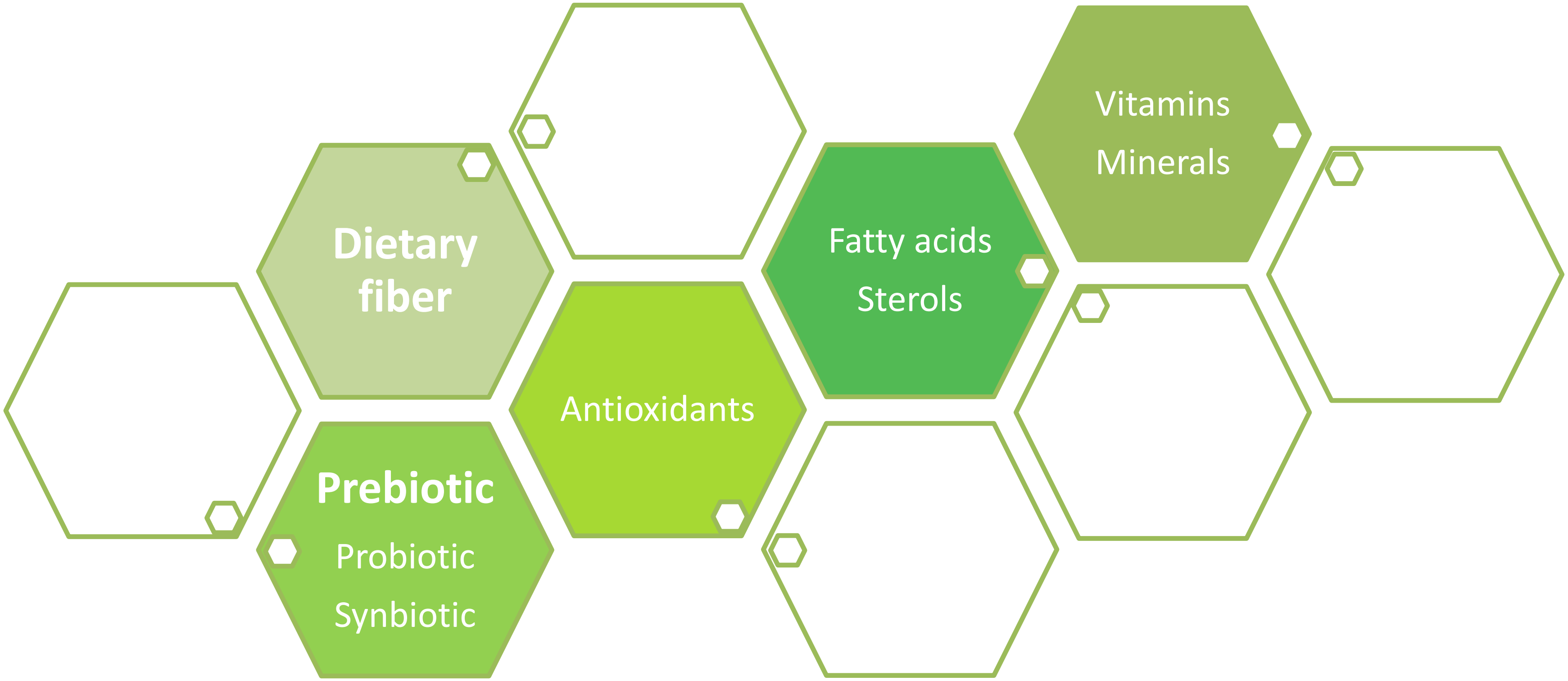

Fig. 3. 'Functional food' components

International Food Information Council, 2011

Introduction

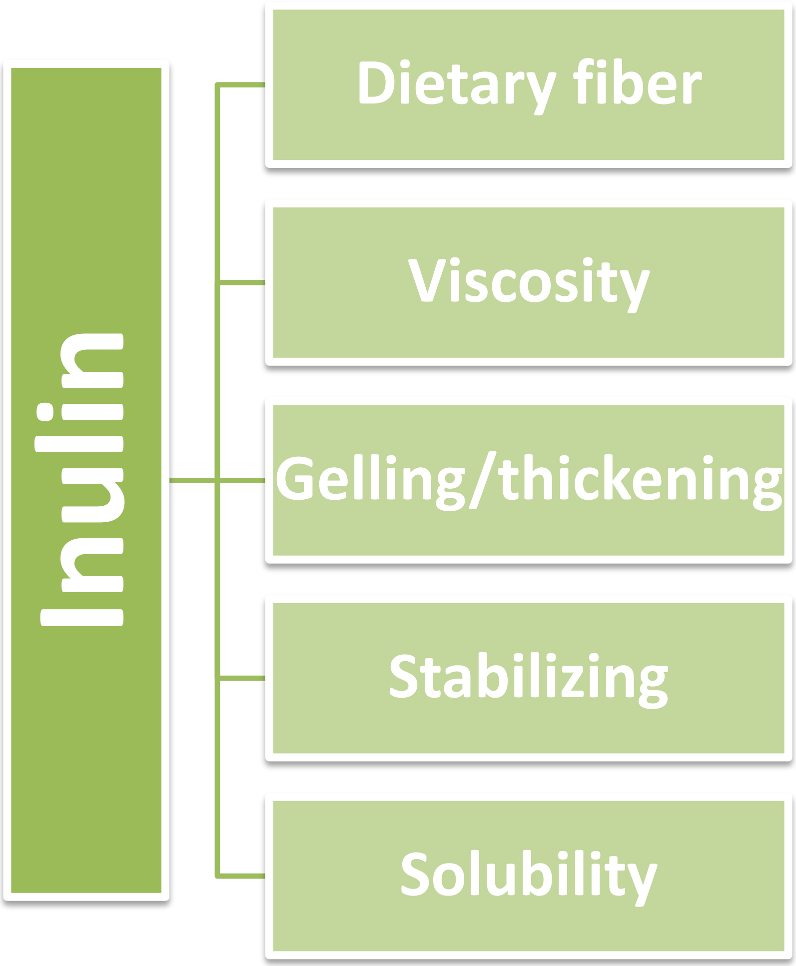

Fig. 4. The major techno-functional properties of inulin

Introduction

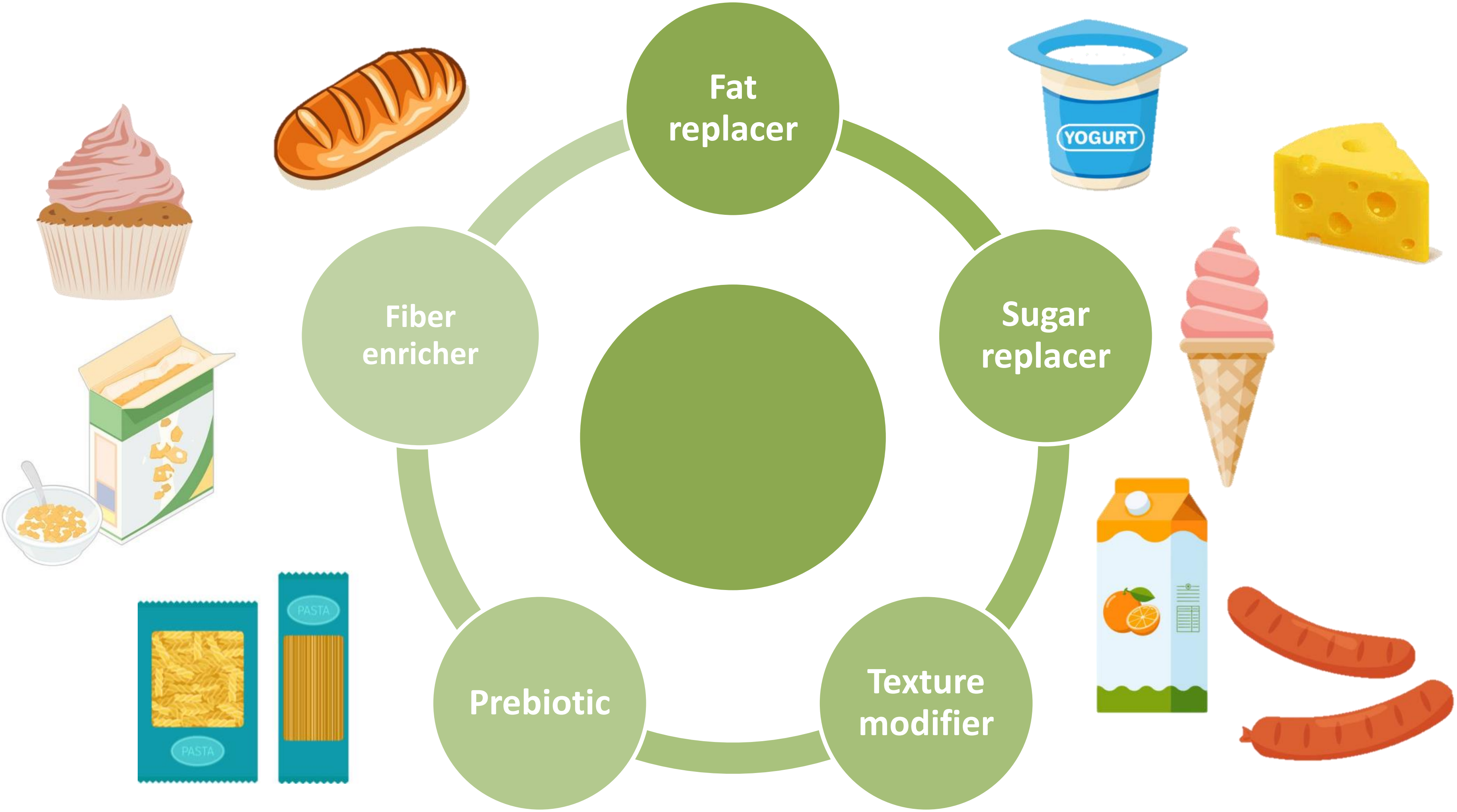

Fig. 5. The major roles of inulin in food industry

Jackson et al., 2022

Technological properties

Table 1. Influence of inulin on technological properties of pasta

Inulin type and properties	Pasta shape/ type	Major findings in technological properties	References
Commercial (ND): 4%[a]	Turkish noodle	Moisture↑, volume increase↑, CT↓, WA↑, CL↓, Color(Raw): L*↑, a*↓, b*↑; Color(Cooked): L*↓, a*↑, b*↑, Texture(Raw): firmness↑, total shearing force↑; Texture(Cooked): hardness↔, adhesiveness↑, Sensory(Raw): color↓^, apperance↔^, fragility↑^; Sensory(Cooked): color↑^, hardness↓^, chewability↓^, taste↓^	Saraç, 2021
Commercial (average DP≥23): 5[a] and 10%[a]	_	CT↓^, SI↓^, CL↑^, Color(Raw): L*↑, a*↓, b*↑, Texture(Cooked): firmness: ↓^(5%), ↑^(10%)	Zarroug et al., 2022
Commercial (average DP≥23): 0.5%	Gluten-free noodle	Diameter↑, extrusion force↔, CT↑, WA↑, SI↑, CL↓, Color(Raw): L*↓, a*↔,, b*↓; Color(Cooked): L*↑, a*↑, b*↑, Texture(Raw): firmness↑, work of shear↑, hardness↓, adhesiveness↓, chewiness↑, resilience↑; Texture(Cooked): firmness↑, work of shear↔, hardness↔, adhesiveness↑, chewiness↓, resilience↔	Gasparre and Rosell, 2019[b]
Extracted from artichoke roots: 5[a], 10[a], and 15%[a]	Fresh tagliatelle	Moisture↓(except 15%), CT↑^, WA↔, SI↓, CL↑, Color(Raw): L*↓, a*↑, b*↓, Color(Cooked): L*↓, a*↑, b*↓, Texture(Raw): firmness↑, Texture(Cooked): firmness↑, Sensory: color↑, firmness, bulkiness↔, adhesiveness↔, odour, taste↓	Difonzo et al., 2022
Extracted from cardoon roots (H-DP), Commercial (L-DP= average DP: 20-25): 2 and 4%	–	CT↓^, SI: ↓(L-DP); ↑(H-DP), WA: ↓(L-DP); ↔(2% H-DP), ↑(4% H-DP), CL↑, Texture(Cooked): hardness↓, adhesiveness↑(except 2% H-DP), Sensory(Dried): color↔, break to resistance↔, overall quality↔; Sensory(Cooked): color↔, firmness↓, elasticity↔, bulkiness↓, adhesiveness↓, taste↔, overall quality↓ (except 4% H-DP)	Padalino et al., 2017
Commercial (average DP≥10, average DP≥23): 15%[a]	–	Moisture↑, CT↑^, WA↑, SI↑, CL↑, Color(Raw): L*↓, a*↑(DP≥10), a*↔(DP≥23), b*↓(DP≥10), b*↔ (DP≥23); Color(Cooked): L*↑, a*↑, b*↓, Texture(Cooked): firmness↓(DP≥10); ↔(DP≥23), maximal breaking strength: ↓(DP≥10); ↔(DP≥23)	Foschia et al., 2015

↓ indicates increment is statistically different, ↑ indicates decrease is statistically different, ↔ indicates increment or decrease is not statistically different, ^ Results were not given statistically, a: concentration was given as a flour replacement ratio, b: in the case of constant hydration, c: in the case of eggless pasta, CL: cooking loss, CT: cooking time, H-DP: high polymerization degree, L-DP: low polymerization degree; ND: not defined SI: swelling index, WA: water absorption

Technological properties

Table 1. Influence of inulin on technological properties of pasta (*continued*)

Inulin type and properties	Pasta shape/ type	Major findings in technological properties	References
Commercial (average DP: ≈8-13): 2.5, 5, 7.5, and 10%	–	Dry matter↑, WA↓^, SI↓, CL↔, Texture(Cooked): firmness↓^, adhesivenes↔, elasticity↓(except 5%)	Brennan et al., 2004
Commercial (average DP≥23): 2.5, 5, 7.5, and 10%	–	WA↓, SI↓, CL↑, Color(Cooked): *L**↑, *a**↔(except 2.5%), *b**↓, Texture(Cooked): hardness↓, chewiness↓, springiness: ↔(2.5%, 5%); ↓ (7.5%, 10%), cohesiveness↔	Bustos et al., 2011
Commercial (average DP>20): 5[a], 10[a], and 15%[a]	Macaroni	Moisture(Dried)↑^(except 5%)	Manno et al., 2009
Commercial (average DP: 8-13), 7.5[a], 10[a], 12.5[a], and 15% [a]	Spaghetti	Dry matter(raw)↑, dry matter(cooked): ↓(7.5 and 10%); ↔(12.5%); ↑(15%), SI: ↑(7.5 and 10%); ↔(12.5%), ↓(15%), CL↑, Texture(Cooked): firmness (peak force)↔, adhesiveness↑(except 7.5%), stickiness: ↓(7.5 and 10%); ↑(12.5 and 15%), elasticity↓, DSC: T_{onset}↑^(except15%), T_{endset}↑^, enthalpy↓, gelatinization temperature↔ (except 15%)	Tudorică et al., 2011
Commercial (average DP≥10, DP≥23): 15%[a]	Spaghetti	Moisture↓, CL↑, Color(Raw): *L**: ↓(DP≥10),; ↔(DP≥23), *a**↓, *b**↓, Texture(Cooked): firmness↓, stickness↑	Peressini et al., 2020
Commercial (average DP: 8-1): 2.5[a], 5[a], 7.5[a], and 10%[a]	Spaghetti	SI↓^, CL↑^, Texture(Cooked): firmness↓^, stickiness↑^, adhesiveness↑^, elasticity↓^	Brennan andTudorică, 2007
Commercial (average DP≥23): 10[a] and 20%	Spaghetti	Color: *L**↑, *a**↓, *b**↑, Texture: hardness: ↔(10%); ↓(20%), adhesiveness↓, work of shear↓	Filipović et al., 2015a
Commercial (average DP≥23): 5, 10, and 20%	–	Color(Cooked): *L*↔, *a**↔, *b**↔, Texture(Cooked): hardness↓, adhesiveness↑, work of shear↓	Filipović et al., 2015b
Extracted from Jerusalem artichoke tubers: 1, 2, and 3%	–	Color: *L**↓^, *a**↑^, *b**↑^, Texture: hardness↑^, cohesiveness↓^, springiness↔^	Singthong et al., 2020
Commercial (average DP>10): 5[a], 10[a], and 20%[a]	–	Color: *L*↔, *a**↔, *b**↔, Texture(Cooked): hardness↓, adhesiveness↑, work of shear↓	Ivkov et al., 2018
Commercial (average DP≥23): 5 and 10%		Color: *L**: ↔(5%); ↑(10%), *b**↑, Texture(Cooked): hardness↓, adhesiveness↑, toughness↓	Filipović et al., 2014

↓ indicates increment is statistically different, ↑ indicates decrease is statistically different, ↔ indicates increment or decrease is not statistically different, ^ Results were not given statistically, a: concentration was given as a flour replacement ratio, b: in the case of constant hydration, c: in the case of eggless pasta, CL: cooking loss, CT: cooking time, H-DP: high polymerization degree, L-DP: low polymerization degree; ND: not defined SI: swelling index, WA: water absorption

Nutritional properties

Table 2. Influence of inulin on nutritionalproperties of pasta

Inulin type and properties	Pasta shape/ type	Major findings in nutritional properties	References
Commercial (ND): 4%[a]	Turkish noodle	Ash↑, dietary fiber↑	Saraç, 2021
Extracted from artichoke roots: 5[a], 10[a], and 15%[a]	Fresh tagliatelle	Protein↓, lipid↓, carbohydrate↓ (except 5%), total dietary fiber↑, ash↑(except 5%); hydrolysis index↓, predicted glycemic index↓, probiotic cell density	Dionzo et al., 2022
Extracted from cardoon roots (H-DP), Commercial (L-DP= average DP: 20-25): 2 and 4%	–	Protein↓(except 2% H-DP), lipid↑ (except 4% L-DP), available carbohydrate↓, total dietary fiber↑, soluble dietary fiber↑, insoluble dietary fiber↑, starch digestibility↓	Padalino et al., 2017
Commercial (average DP>20): 5[a], 10[a], and 15%[a]	Macaroni	Protein↓^, starch↓^, ash↓^	Manno et al., 2009
Commercial (average DP: 8-1): 2.5[a], 5[a], 7.5[a], and 10%[a]	Spaghetti	Protein↓^, carbohydrate↓^, starch↓^, total non-starch polysaccharide↑^	Brennan and Tudorică, 2007
Commercial (average DP≥23): 10[a] and 20%[a]	Spaghetti	Protein↓, lipid↓, sugar↓, starch↓, cellulose↑, ω-3 fatty acids content↔, total dietary fiber↑	Filipović et al., 2015a
Commercial (average DP≥23): 5[a], 10[a], and 20%[a]	–	Protein↓(except 5%), lipid↓, sugar↑, starch↓, cellulose↑, dietary fiber↑, non-digestible carbohydrates↑, energy↓^	Filipović et al., 2015b
Commercial (average DP>10): 5[a], 10[a], and 20%[a]	–	Protein↓(except 5%), lipid↓, sugar↑, starch↓, cellulose↑, dietary fiber↑, non-digestible carbohydrates↑, energy↓	Ivkov et al., 2018
Commercial (average DP≥23): 5 and 10%	–	Protein↓, lipid↔, sugar↑, starch↓, cellulose↑	Filipović et al., 2014

↓ indicates increment is statistically different, ↑ indicates decrease is statistically different, ↔ indicates increment or decrease is not statistically different, ^ Results were not given statistically, a: concentration was given as a flour replacement ratio, b: in the case of constant hydration, c: in the case of eggless pasta, CL: cooking loss, CT: cooking time, H-DP: high polymerization degree, L-DP: low polymerization degree; ND: not defined SI: swelling index, WA: water absorption

Nutritional properties

Table 2. Influence of inulin on nutritionalproperties of pasta (*continued*)

Major findings in nutritional properties	References
Starch hydrolysis index↓, pGI↓	Difonzo et al., 2022
Starch digestibility↓ (more prominent in H-DP in pasta)	Padalino et al., 2017
pGI↔ (except durum wheat cultivar)	Garbetta et al., 2020
Reducing sugar relase↓	Foschia et al., 2015
Reducing sugar relase↓ Pasta digestion decreased with increasing inulin addition pGI↔ (GI% decrease from control was 15% in inulin-added pasta at 10% concentration)	Brennan and Tudorică, 2004
Higher reducing sugar t release at 20 min than β-glucan extract, psyllium Similar reducing sugar t release with control at 60 min and 120 mİn IAUC↑	Peressini et al., 2020

↓ indicates increment is statistically different; ↑ indicates decrease is statistically different.; ↔ indicates increment or decrease is not statistically different; IAUC: incremental area under the curve

Human health

Table 3. Influence of inulin in pasta on human health

Major findings	References
Significantly lower *in vivo* postprandial glucose levels (90 min and 120 min after meal) were obtained and the **glycemic index was nearly 70%** in inulin-enriched protein pasta for dietary management of chronic kidney disease in patients with type 2 diabetes (*n*=14)	Tubili et al., 2016
There were **no significant differences in total cholesterol HDL-cholesterol, triglycerides, and blood glucose, the total weight loss** and also the **level of insulin and HbA1c after glucose load was reduced** in obese subjects (*n*=30) adherent to the low-calories diet which included 2% chicory inulin-enriched pasta.	Hassan et al., 2020
While many soluble dietary fibers (β-glucan, arabinoxylan, fructooligosaccharides, galactose oligosaccharides, xylooligosaccharides, and arabinogalactan) **significantly increased protein hydrolysis** of multigrain noodles throughout gastrointestinal digestion, **and thus protein digestion** for school-age children, **inulin did not.**	Gao et al., 2023

CONCLUSION

- As a consequence, although many studies which were based on using different types with different polymerization degree and concentrations of inulin in pasta formulations were carried out, still limited data is available on the possibility of utilizing in gluten-free pasta formulations based on different raw materials.
- As far as we know, the effect of low- and high-temperature drying procedures on inulin-based pasta did not examined, yet.
- On the other side, inulin was generally involved in noodle and spaghetti-type pasta, therefore the usage availability on pasta with different shapes such as short-cut pasta could be beneficial.
- More studies are still needed to assess *in vitro* and *in vivo* starch digestibility.
- Moreover, the synbiotic potential in pasta formulations with different probiotics should also be evaluated in pasta.
- The following studies should also deal with the optimization of inulin extraction from different plants and also process parameters of pasta production such as extrusion and drying for the commercialization potential of inulin-enriched pasta.

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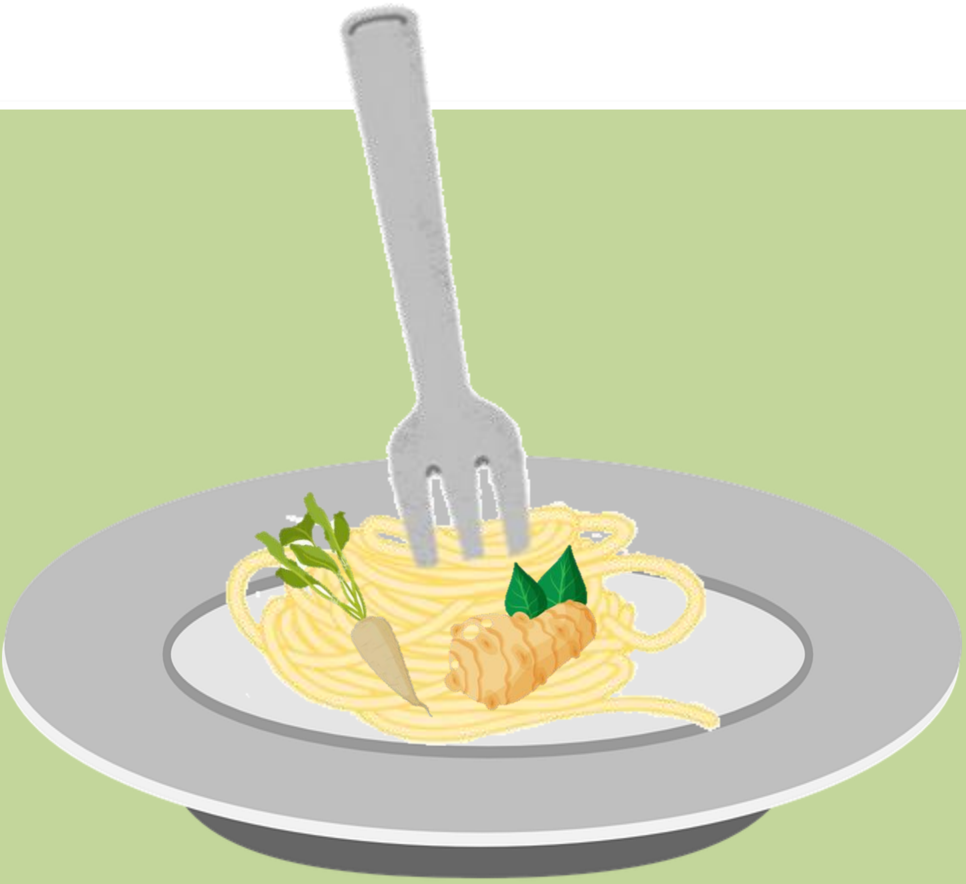

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