

**DANI  
DOKTORATA  
BIOTEHNIČKOG  
PODRUČJA**

12. i 13. rujna 2024.



# Application of 3D printing technology in the production of a functional snack product based on strawberry and strawberry tree fruit

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# 3D FOOD PRINTING

→ 3D printing is an additive manufacturing process in which computer models enable the production of 3D-printed food.



3D FOOD  
PRINTER

## ADVANTAGES

- Customized products
- Different forms
- Use of alternative sources (e.g. food waste)
- "Zero waste" technology
- Reduction of global energy consumption - sustainability

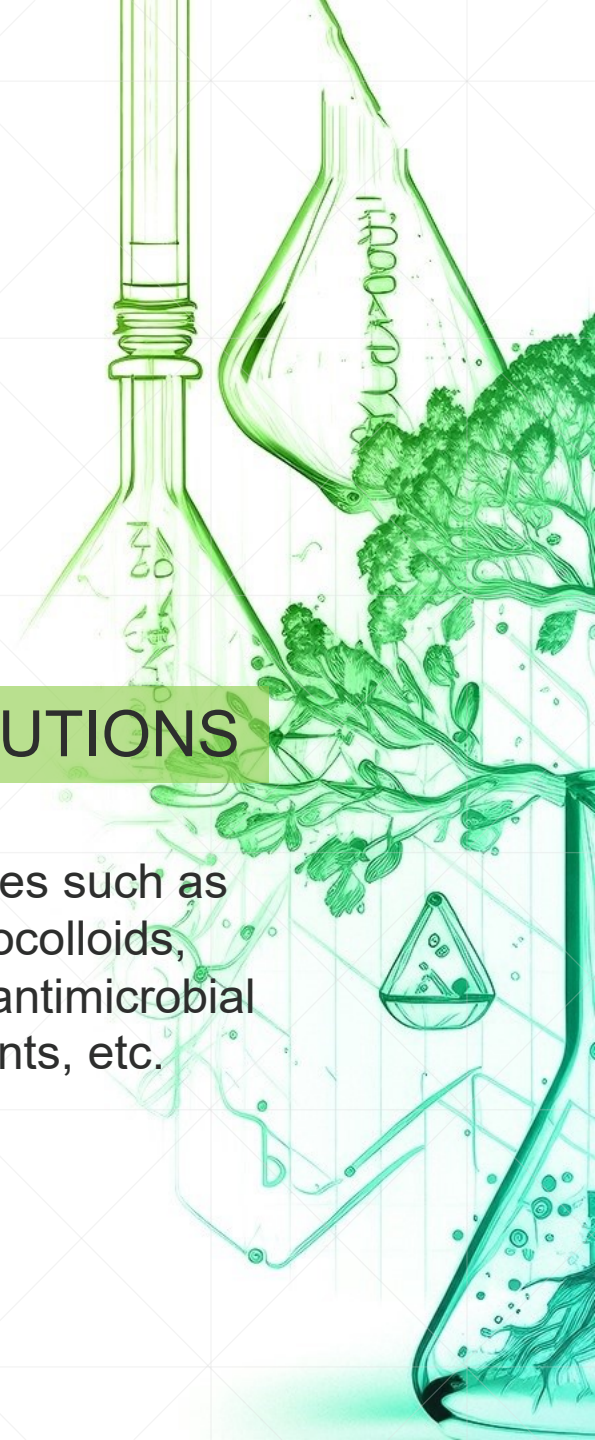
- The inability to print all raw foods
- Health safety



## DISADVANTAGES

## SOLUTIONS

Additives such as hydrocolloids, natural antimicrobial agents, etc.







*Fragaria x ananassa* Duch.  
– strawberry

- distribution area: Croatia, world
- high nutritional and biochemical potential with antioxidant activity
- has numerous health benefits
- demanding raw material for 3D printing

*Arbutus unedo* L. – strawberry tree fruit

- distribution area: Mediterranean region- leaves, fruits, bark and root are used in folk medicine- rich source of bioactive compounds with antioxidant activity- has numerous health benefits

👉 high crude fiber content



# Production of 3D printed snacks



**STRAWBERRY**  
(*Fragaria ananassa* x Duch.)

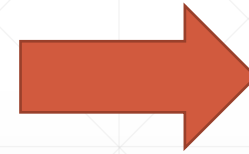


**STRAWBERRY TREE FRUIT**  
(*Arbutus unedo* L.)

1 : 1



Fruit mixture  
preparation with  
addition of  
wheat starch: 6%, 8%  
and 10%



**3D  
PRINTING**





# 3D printing of Fruit Snacks

	Program 1 (P1)	Program 2 (P2)
the printing speed	8000 mm min <sup>-1</sup>	14000 mm min <sup>-1</sup>
printing line thickness	3.5 mm	3.4 mm
mixture flow rate	1.4	1.65
nozzle height of the first layer	6 mm	4.5 mm



The dimensions of the 3D-printed objects were 53 mm (length) × 51 mm (width) × 12 mm (height).



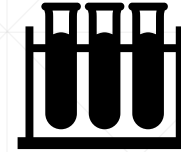
Experimental plan for 3DP of fruit snacks.

Sample ID	Starch Content (%)	3D Program
1	0	P1
2	0	P2
3	6	P1
4	6	P2
5	8	P1
6	8	P2
7	10	P1
8	10	P2

# Analytics:

## Determination of Polyphenolic Compounds:

- Total Phenolic Content (TPC)
- Total Flavonoids (TF)
- Total Hydroxycinnamic Acids (HCAs) and Total Flavonols (FLs)
- Condensed Tannins (CTs)



## Determination of Pigments:

- Total Monomeric Anthocyanins (ANTs)
- Total Carotenoids (CARs)
- Chlorophyll A (CHL A) and Chlorophyll B (CHL B)



## *In Vitro* Antioxidant Capacity (AOC)

- DPPH and FRAP method



## Determination of Rheological Properties



## Determination of Instrumental Color: CIELab

## Sensory Evaluation of 3D-Printed Snacks



# Relationship of 3DP parameters with the content of bioactive compounds in the 3DP samples

Variable	n	TPC	HCA	FL	TF	CT
Starch level		$p \leq 0.01^{\dagger}$	$p \leq 0.01^{\dagger}$	$p \leq 0.01^{\dagger}$	$p \leq 0.01^{\dagger}$	$p \leq 0.01^{\dagger}$
0%	4	$429.50 \pm 5.87^a$	$84.99 \pm 0.73^a$	$55.41 \pm 0.54^a$	$10.66 \pm 0.22^a$	$171.33 \pm 1.66^a$
6%	4	$392.96 \pm 5.87^b$	$78.16 \pm 0.73^b$	$52.55 \pm 0.54^b$	$9.65 \pm 0.22^b$	$141.87 \pm 1.66^b$
8%	4	$353.60 \pm 5.87^c$	$71.11 \pm 0.73^c$	$49.25 \pm 0.54^c$	$9.90 \pm 0.22^{a,b}$	$141.41 \pm 1.66^b$
10%	4	$344.21 \pm 5.87^c$	$64.89 \pm 0.73^d$	$42.16 \pm 0.54^d$	$9.22 \pm 0.22^b$	$147.59 \pm 1.66^b$
3DP Program		$p = 0.43^{\ddagger}$	$p \leq 0.01^{\dagger}$	$p = 0.05^{\ddagger}$	$p = 0.17^{\ddagger}$	$p = 0.34^{\ddagger}$
Program 1	8	$382.48 \pm 4.15^a$	$76.45 \pm 0.52^a$	$50.47 \pm 0.38^a$	$9.69 \pm 0.15^a$	$149.71 \pm 1.17^a$
Program 2	8	$377.65 \pm 4.15^a$	$73.12 \pm 0.52^b$	$49.22 \pm 0.38^a$	$10.02 \pm 0.15^a$	$151.39 \pm 1.17^a$
Dataset average	16	$380.07 \pm 9.09$	$74.79 \pm 2.03$	$49.84 \pm 1.31$	$9.86 \pm 0.16$	$150.56 \pm 3.31$

Results are expressed as mean  $\pm$  standard error. Values represented with different letters are statistically different at  $p \leq 0.05$ ;  $\dagger$  significant factor in multifactor analysis; and  $\ddagger$  not significant factor in multifactor analysis. TPC—total phenolic content (mg GAE 100 g<sup>-1</sup>); HCAs—hydroxycinnamic acids (mg CAE 100 g<sup>-1</sup>); FLs—flavonols (mg QE 100 g<sup>-1</sup>); TFs—total flavonoids (mg QE 100 g<sup>-1</sup>); and CTs— condensed tannins (mg CE 100 g<sup>-1</sup>).

# Relationship between 3DP parameters and the content of pigments and antioxidant capacity in the 3D printed snacks

Variable	n	ANT	CAR	CHLA	CHLB	DPPH	FRAP
Starch level		$p \leq 0.01^{\dagger}$	$p \leq 0.01^{\dagger}$	$p \leq 0.01^{\dagger}$	$p \leq 0.01^{\dagger}$	$p = 0.07^{\ddagger}$	$p = 0.03^{\dagger}$
0%	4	$9.65 \pm 0.16^a$	$0.58 \pm 0.002^b$	$0.24 \pm 0.01^a$	$0.40 \pm 0.01^a$	$2.90 \pm 0.07^a$	$290.38 \pm 0.35^{a,b}$
6%	4	$7.75 \pm 0.16^b$	$0.62 \pm 0.002^a$	$0.11 \pm 0.01^b$	$0.18 \pm 0.01^b$	$3.00 \pm 0.07^a$	$289.95 \pm 0.35^{a,b}$
8%	4	$7.73 \pm 0.16^b$	$0.52 \pm 0.002^c$	$0.11 \pm 0.01^b$	$0.17 \pm 0.01^b$	$2.74 \pm 0.07^a$	$290.82 \pm 0.35^a$
10%	4	$8.09 \pm 0.16^b$	$0.48 \pm 0.002^d$	$0.12 \pm 0.01^b$	$0.19 \pm 0.01^b$	$2.73 \pm 0.07^a$	$288.94 \pm 0.35^b$
3DP Program		$p = 0.64^{\ddagger}$	$p = 0.11^{\ddagger}$	$p = 0.12^{\ddagger}$	$p = 0.19^{\ddagger}$	$p = 0.15^{\ddagger}$	$p = 0.73^{\ddagger}$
Program 1	8	$8.35 \pm 0.11^a$	$0.55 \pm 0.001^a$	$0.15 \pm 0.004^a$	$0.25 \pm 0.01^a$	$2.90 \pm 0.05^a$	$289.96 \pm 0.25^a$
Program 2	8	$8.27 \pm 0.11^a$	$0.55 \pm 0.001^a$	$0.14 \pm 0.004^a$	$0.23 \pm 0.01^a$	$2.78 \pm 0.05^a$	$290.08 \pm 0.25^a$
Dataset average	16	$8.31 \pm 0.22$	$0.55 \pm 0.01$	$0.14 \pm 0.01$	$0.24 \pm 0.03$	$2.84 \pm 0.05$	$290.02 \pm 0.26$

Results are expressed as mean  $\pm$  standard error. Values represented with different letters are statistically different at  $p \leq 0.05$ ;  $\dagger$  significant factor in multifactor analysis; and  $\ddagger$  not significant factor in multifactor analysis. ANT—monomeric anthocyanin (mg Cy-3-Glc 100 g<sup>-1</sup>); CAR—total carotenoid (mg 100 g<sup>-1</sup>); CHL A—total chlorophyll A (mg 100 g<sup>-1</sup>); CHL B—total chlorophyll B (mg 100 g<sup>-1</sup>); DPPH assay ( $\mu$ mol TE 100 g<sup>-1</sup>); and FRAP assay (mmol TE 100 g<sup>-1</sup>).



# Influence of 3DP process parameters on texture, particle diameters and dimension in 3D printed snacks expressed by *p*-value \*

Parameter	3DP Program	Starch Content (%)
F	0.725588	0.695556
W	0.725577	0.695550
F <sub>p</sub>	0.178047	0.158750
W <sub>p</sub>	0.236516	0.876531
D [3.2]	0.949818	0.003742 *
D [4.3]	0.660607	0.024213 *
d [0.1]	0.730548	0.029678 *
d [0.5]	0.616439	0.004638 *
d [0.9]	0.603835	0.037802 *
Length	0.147469	0.754530
Width	0.659869	0.795063
Height	0.122649	0.334880

\* Results are statistically significant at  $p \leq 0.05$ .

The samples with the maximum starch content results from increased sample firmness.

Smaller particles with a higher starch content improved the stability of the sample

# Relationship between 3DP parameters and the color parameters in the 3D printed snacks

Variable	n	L	a	b	C	H	$\Delta E$
Starch level		$p \leq 0.01^\dagger$	$p = 0.05^\ddagger$	$p \leq 0.01^\dagger$	$p \leq 0.01^\dagger$	$p \leq 0.01^\dagger$	$p \leq 0.01^\dagger$
0%	4	$41.43 \pm 0.19^c$	$22.92 \pm 0.39^a$	$14.44 \pm 0.30^b$	$27.09 \pm 0.46^b$	$32.23 \pm 0.37^b$	$0.00 \pm 0.41^c$
6%	4	$46.74 \pm 0.19^a$	$24.48 \pm 0.39^a$	$16.98 \pm 0.30^a$	$29.80 \pm 0.46^a$	$34.74 \pm 0.37^a$	$6.17 \pm 0.41^a$
8%	4	$44.79 \pm 0.19^b$	$23.45 \pm 0.39^a$	$15.70 \pm 0.30^{a,b}$	$28.22 \pm 0.46^{a,b}$	$33.80 \pm 0.37^{a,b}$	$3.89 \pm 0.41^b$
10%	4	$44.19 \pm 0.19^b$	$22.77 \pm 0.39^a$	$14.82 \pm 0.30^b$	$27.17 \pm 0.46^b$	$33.06 \pm 0.37^{a,b}$	$3.00 \pm 0.41^b$
3DP Program		$p = 0.29^\ddagger$	$p = 0.71^\ddagger$	$p = 0.35^\ddagger$	$p = 0.93^\ddagger$	$p = 0.11^\ddagger$	$p = 0.15^\ddagger$
Program 1	8	$44.18 \pm 0.13^a$	$23.48 \pm 0.27^a$	$15.34 \pm 0.21^a$	$28.05 \pm 0.32^a$	$33.13 \pm 0.26^a$	$3.59 \pm 0.29^a$
Program 2	8	$44.39 \pm 0.13^a$	$23.33 \pm 0.27^a$	$15.64 \pm 0.21^a$	$28.09 \pm 0.32^a$	$33.79 \pm 0.26^a$	$2.94 \pm 0.29^a$
Dataset average	16	$44.29 \pm 0.50$	$23.40 \pm 0.25$	$15.49 \pm 0.29$	$28.07 \pm 0.35$	$33.46 \pm 0.31$	$3.26 \pm 0.60$

Results are expressed as mean  $\pm$  standard error. Values represented with different letters are statistically different at  $p \leq 0.05$ ;  $^\dagger$  significant factor in multifactor analysis; and  $^\ddagger$  not significant factor in multifactor analysis. L\*—lightness; a\*—redness; b\*—yellowness; C\*—chroma; H\*—hue; and  $\Delta E$ — color change.

# Characterization of the sensory properties of 3D printed snacks

added in two different concentrations



Saccharose

Fructose

Birch sugar (xylitol)

Date syrup

Erythritol

Stevia and erythritol

Maple syrup

Agave syrup





# Sensory comparison results of 3D printed snacks with the addition of different sweeteners in two different concentrations

Variable	n	Intensity of Orange Color	Strawberry Odor	Off-Odor	Strawberry Flavor	Strawberry Tree Fruit Flavor	Off-Flavor	Sweet Taste	Sour Taste	Harmony Taste	Off-Taste	Homogeneity	Glossy Appearance
Sample		$p = 0.81 \uparrow$	$p = 0.76 \uparrow$	$p = 0.99 \uparrow$	$p = 0.07 \uparrow$	$p = 0.99 \uparrow$	$p = 0.41 \uparrow$	$p \leq 0.01 \uparrow$	$p = 0.14 \uparrow$	$p \leq 0.01 \uparrow$	$p = 0.67 \uparrow$	$p = 0.71 \uparrow$	$p = 0.09 \uparrow$
A	13	$5.85 \pm 0.32^a$	$5.38 \pm 0.37^a$	$1.23 \pm 0.19^a$	$4.46 \pm 0.38^a$	$4.15 \pm 0.45^a$	$1.15 \pm 0.18^a$	$2.46 \pm 0.36^d$	$4.69 \pm 0.38^a$	$3.69 \pm 0.34^{ab}$	$1.15 \pm 0.18^a$	$5.15 \pm 0.41^a$	$5.77 \pm 0.35^a$
B1	13	$5.92 \pm 0.32^a$	$5.08 \pm 0.37^a$	$1.08 \pm 0.19^a$	$4.92 \pm 0.38^a$	$3.54 \pm 0.45^a$	$1.08 \pm 0.18^a$	$4.46 \pm 0.36^{ab}$	$3.23 \pm 0.38^a$	$4.85 \pm 0.34^{ab}$	$1.08 \pm 0.18^a$	$4.77 \pm 0.41^a$	$5.77 \pm 0.35^a$
B2	13	$6.08 \pm 0.32^a$	$5.00 \pm 0.37^a$	$1.23 \pm 0.19^a$	$4.85 \pm 0.38^a$	$3.46 \pm 0.45^a$	$1.08 \pm 0.18^a$	$5.00 \pm 0.36^{ab}$	$2.92 \pm 0.38^a$	$4.85 \pm 0.34^{ab}$	$1.08 \pm 0.18^a$	$5.15 \pm 0.41^a$	$6.08 \pm 0.35^a$
C1	13	$6.15 \pm 0.32^a$	$4.85 \pm 0.37^a$	$1.31 \pm 0.19^a$	$4.31 \pm 0.38^a$	$3.46 \pm 0.45^a$	$1.23 \pm 0.18^a$	$3.92 \pm 0.36^{abcd}$	$3.31 \pm 0.38^a$	$4.54 \pm 0.34^{ab}$	$1.23 \pm 0.18^a$	$5.38 \pm 0.41^a$	$5.92 \pm 0.35^a$
C2	13	$5.92 \pm 0.32^a$	$4.77 \pm 0.37^a$	$1.23 \pm 0.19^a$	$4.31 \pm 0.38^a$	$3.23 \pm 0.45^a$	$1.23 \pm 0.18^a$	$4.77 \pm 0.36^{ab}$	$2.92 \pm 0.38^a$	$4.85 \pm 0.34^{ab}$	$1.08 \pm 0.18^a$	$5.31 \pm 0.41^a$	$6.15 \pm 0.35^a$
D1	13	$6.08 \pm 0.32^a$	$4.69 \pm 0.37^a$	$1.38 \pm 0.19^a$	$3.92 \pm 0.38^a$	$3.46 \pm 0.45^a$	$1.38 \pm 0.18^a$	$3.38 \pm 0.36^{bcd}$	$3.92 \pm 0.38^a$	$3.54 \pm 0.34^b$	$1.38 \pm 0.18^a$	$5.38 \pm 0.41^a$	$5.38 \pm 0.35^a$
D2	13	$6.23 \pm 0.32^a$	$4.92 \pm 0.37^a$	$1.08 \pm 0.19^a$	$4.15 \pm 0.38^a$	$3.46 \pm 0.45^a$	$1.08 \pm 0.18^a$	$4.00 \pm 0.36^{abcd}$	$3.54 \pm 0.38^a$	$4.31 \pm 0.34^{ab}$	$1.23 \pm 0.18^a$	$5.38 \pm 0.41^a$	$5.46 \pm 0.35^a$
E1	13	$6.08 \pm 0.32^a$	$4.23 \pm 0.37^a$	$1.31 \pm 0.19^a$	$3.54 \pm 0.38^a$	$3.69 \pm 0.45^a$	$1.23 \pm 0.18^a$	$2.69 \pm 0.36^{cd}$	$4.15 \pm 0.38^a$	$3.23 \pm 0.34^b$	$1.46 \pm 0.18^a$	$5.38 \pm 0.41^a$	$4.69 \pm 0.35^a$
E2	13	$6.15 \pm 0.32^a$	$4.15 \pm 0.37^a$	$1.23 \pm 0.19^a$	$3.46 \pm 0.38^a$	$3.54 \pm 0.45^a$	$1.31 \pm 0.18^a$	$3.54 \pm 0.36^{abcd}$	$4.08 \pm 0.38^a$	$3.85 \pm 0.34^{ab}$	$1.23 \pm 0.18^a$	$5.38 \pm 0.41^a$	$4.62 \pm 0.35^a$
F1	13	$5.54 \pm 0.32^a$	$5.15 \pm 0.37^a$	$1.31 \pm 0.19^a$	$4.62 \pm 0.38^a$	$3.38 \pm 0.45^a$	$1.15 \pm 0.18^a$	$4.15 \pm 0.36^{abcd}$	$3.62 \pm 0.38^a$	$4.38 \pm 0.34^{ab}$	$1.08 \pm 0.18^a$	$5.00 \pm 0.41^a$	$5.77 \pm 0.35^a$
F2	13	$5.38 \pm 0.32^a$	$4.92 \pm 0.37^a$	$1.15 \pm 0.19^a$	$5.15 \pm 0.38^a$	$3.38 \pm 0.45^a$	$1.15 \pm 0.18^a$	$4.62 \pm 0.36^{ab}$	$3.31 \pm 0.38^a$	$4.69 \pm 0.34^{ab}$	$1.23 \pm 0.18^a$	$5.38 \pm 0.41^a$	$5.69 \pm 0.35^a$
G1	13	$5.62 \pm 0.32^a$	$4.69 \pm 0.37^a$	$1.31 \pm 0.19^a$	$4.00 \pm 0.38^a$	$3.62 \pm 0.45^a$	$1.54 \pm 0.18^a$	$3.62 \pm 0.36^{abcd}$	$3.92 \pm 0.38^a$	$3.92 \pm 0.34^{ab}$	$1.62 \pm 0.18^a$	$5.54 \pm 0.41^a$	$5.31 \pm 0.35^a$
G2	13	$5.62 \pm 0.32^a$	$5.00 \pm 0.37^a$	$1.38 \pm 0.19^a$	$4.46 \pm 0.38^a$	$3.38 \pm 0.45^a$	$1.38 \pm 0.18^a$	$4.00 \pm 0.36^{abcd}$	$3.54 \pm 0.38^a$	$4.31 \pm 0.34^{ab}$	$1.38 \pm 0.18^a$	$5.69 \pm 0.41^a$	$5.54 \pm 0.35^a$
H1	13	$5.54 \pm 0.32^a$	$4.85 \pm 0.37^a$	$1.31 \pm 0.19^a$	$4.62 \pm 0.38^a$	$3.62 \pm 0.45^a$	$1.15 \pm 0.18^a$	$4.38 \pm 0.36^{abc}$	$3.62 \pm 0.38^a$	$4.38 \pm 0.34^{ab}$	$1.38 \pm 0.18^a$	$5.38 \pm 0.41^a$	$4.46 \pm 0.35^a$
H2	13	$5.54 \pm 0.32^a$	$5.08 \pm 0.37^a$	$1.23 \pm 0.19^a$	$5.08 \pm 0.38^a$	$3.69 \pm 0.45^a$	$1.15 \pm 0.18^a$	$5.15 \pm 0.36^a$	$3.38 \pm 0.38^a$	$5.23 \pm 0.34^a$	$1.23 \pm 0.18^a$	$5.38 \pm 0.41^a$	$5.54 \pm 0.35^a$
I1	13	$5.69 \pm 0.32^a$	$5.15 \pm 0.37^a$	$1.31 \pm 0.19^a$	$4.38 \pm 0.38^a$	$3.54 \pm 0.45^a$	$1.62 \pm 0.18^a$	$4.00 \pm 0.36^{abcd}$	$3.85 \pm 0.38^a$	$4.15 \pm 0.34^{ab}$	$1.46 \pm 0.18^a$	$5.62 \pm 0.41^a$	$5.08 \pm 0.35^a$
I2	13	$5.77 \pm 0.32^a$	$5.15 \pm 0.37^a$	$1.15 \pm 0.19^a$	$4.69 \pm 0.38^a$	$3.54 \pm 0.45^a$	$1.62 \pm 0.18^a$	$4.53 \pm 0.36^{ab}$	$3.85 \pm 0.38^a$	$4.38 \pm 0.34^{ab}$	$1.38 \pm 0.18^a$	$6.00 \pm 0.41^a$	$5.08 \pm 0.35^a$

xylitol

erythritol

agave syrup

## Sensory comparison results of 3D printed snacks with the addition of different sweeteners

Variable	n	Intensity of Orange Color	Strawberry Odor	Off-Odor	Strawberry Flavor	Strawberry Tree Fruit Flavor	Off-Flavor	Sweet Taste	Sour Taste	Harmony Taste	Off-Taste	Homogeneity	Glossy Appearance
Sample grouped		$p = 0.23 \ddagger$	$p = 0.20 \ddagger$	$p = 0.99 \ddagger$	$p \leq 0.01 \dagger$	$p = 0.94 \ddagger$	$p = 0.06 \ddagger$	$p \leq 0.01 \dagger$	$p = 0.01 \dagger$	$p \leq 0.01 \dagger$	$p = 0.27 \ddagger$	$p = 0.23 \ddagger$	$p \leq 0.01 \dagger$
A	13	$5.85 \pm 0.32^a$	$5.38 \pm 0.37^a$	$1.23 \pm 0.19^a$	$4.46 \pm 0.38^{ab}$	$4.15 \pm 0.45^a$	$1.15 \pm 0.18^a$	$2.46 \pm 0.36^b$	$4.69 \pm 0.38^a$	$3.69 \pm 0.34^{ab}$	$1.15 \pm 0.18^a$	$5.15 \pm 0.41^a$	$5.77 \pm 0.35^{ab}$
B	26	$6.00 \pm 0.23^a$	$5.04 \pm 0.26^a$	$1.15 \pm 0.13^a$	$4.88 \pm 0.27^a$	$3.50 \pm 0.32^a$	$1.08 \pm 0.12^a$	$4.73 \pm 0.25^a$	$3.08 \pm 0.27^b$	$4.85 \pm 0.24^a$			$5.92 \pm 0.25^a$
C	26	$6.04 \pm 0.23^a$	$4.81 \pm 0.26^a$	$1.27 \pm 0.13^a$	$4.31 \pm 0.27^{ab}$	$3.35 \pm 0.32^a$	$1.23 \pm 0.12^a$	$4.35 \pm 0.25^a$	$3.12 \pm 0.27^b$	$4.69 \pm 0.24^a$	$1.15 \pm 0.13^a$	$5.35 \pm 0.29^a$	$6.03 \pm 0.25^a$
D	26	$6.15 \pm 0.23^a$	$4.81 \pm 0.26^a$	$1.23 \pm 0.13^a$	$4.04 \pm 0.27^{ab}$	$3.46 \pm 0.32^a$	$1.23 \pm 0.12^a$	$3.69 \pm 0.25^{ab}$	$3.73 \pm 0.27^{ab}$	$3.92 \pm 0.24^{ab}$	$1.31 \pm 0.13^a$	$5.54 \pm 0.29^a$	$5.42 \pm 0.25^{ab}$
E	26	$6.12 \pm 0.23^a$	$4.19 \pm 0.26^a$	$1.27 \pm 0.13^a$	$3.50 \pm 0.27^b$	$3.62 \pm 0.32^a$	$1.27 \pm 0.12^a$	$3.12 \pm 0.25^b$	$4.12 \pm 0.27^{ab}$	$3.54 \pm 0.24^b$	$1.35 \pm 0.13^a$	$5.58 \pm 0.29^a$	$4.65 \pm 0.25^b$
F	26	$5.46 \pm 0.23^a$	$5.04 \pm 0.26^a$	$1.23 \pm 0.13^a$	$4.88 \pm 0.27^a$	$3.38 \pm 0.32^a$	$1.15 \pm 0.12^a$	$4.38 \pm 0.25^a$	$3.46 \pm 0.27^{ab}$	$4.54 \pm 0.24^{ab}$	$1.15 \pm 0.13^a$	$5.19 \pm 0.29^a$	$5.73 \pm 0.25^{ab}$
G	26	$5.62 \pm 0.23^a$	$4.85 \pm 0.26^a$	$1.35 \pm 0.13^a$	$4.23 \pm 0.27^{ab}$	$3.50 \pm 0.32^a$	$1.46 \pm 0.12^a$	$3.81 \pm 0.25^{ab}$	$3.73 \pm 0.27^{ab}$	$4.12 \pm 0.24^{ab}$	$1.50 \pm 0.13^a$	$5.62 \pm 0.29^a$	$5.42 \pm 0.25^{ab}$
H	26	$5.54 \pm 0.23^a$	$4.96 \pm 0.26^a$	$1.27 \pm 0.13^a$	$4.85 \pm 0.27^a$	$3.65 \pm 0.32^a$	$1.15 \pm 0.12^a$	$4.77 \pm 0.25^a$	$3.50 \pm 0.27^{ab}$	$4.81 \pm 0.24^a$			$5.50 \pm 0.25^{ab}$
I	26	$5.73 \pm 0.23^a$	$5.15 \pm 0.26^a$	$1.23 \pm 0.13^a$	$4.54 \pm 0.27^{ab}$	$3.54 \pm 0.32^a$	$1.62 \pm 0.12^a$	$4.27 \pm 0.25^a$	$3.85 \pm 0.27^{ab}$	$4.27 \pm 0.24^{ab}$	$1.42 \pm 0.13^a$	$5.81 \pm 0.29^a$	$5.08 \pm 0.25^{ab}$
Dataset average	221	$5.83 \pm 0.08$	$4.89 \pm 0.09$	$1.25 \pm 0.04$	$4.41 \pm 0.10$	$3.54 \pm 0.11$	$1.27 \pm 0.04$	$4.04 \pm 0.10$	$3.64 \pm 0.09$	$4.30 \pm 0.09$	$1.28 \pm 0.04$	$5.49 \pm 0.10$	$5.49 \pm 0.09$

Results are expressed as mean  $\pm$  standard error. Values represented with different letters are statistically different at  $p \leq 0.05$ ;  $\dagger$  significant factor in multifactor analysis; and  $\ddagger$  not significant factor in multifactor analysis. A—control sample; 3DP fruit snacks with the addition of: B—saccharose, C—fructose, D—birch sugar (xylitol), E—erythritol, F—maple syrup, G—date syrup, H—agave syrup, I—stevia and erythritol; 1—lower level of sweeteners, 2—higher level of sweeteners.



# Conclusions



Increasing the starch content led to a decrease in the content of almost all bioactive compounds, while it had no effect on the antioxidant capacity

The printing program had no significant effect on the bioactive compounds (except hydroxycinnamic acids), antioxidant capacity and color parameters.

A higher starch content improved the strength of the sample but had no effect on the mechanical properties.

In contrast to the programs, varying the starch content had a significant effect on all the color parameters except the  $a^*$  values.

The variations in sweetener content only affected the sweet and harmonious taste.

This study confirms the great potential of fruit bases for the production of 3D-printed snacks with excellent biological and rheological properties.



*Article*

# Characterization of Antioxidant Bioactive Compounds and Rheological, Color and Sensory Properties in 3D-Printed Fruit Snacks

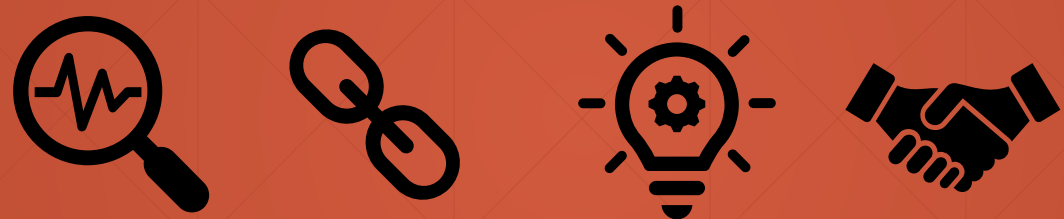
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# THANK YOU FOR YOUR ATENTION!

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