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ABSTRACT

Tomato processing industries generate substantial quantities of waste, mainly seeds and peels, which are often discarded despite being rich sources of bioactive compounds such as lycopene, polyphenols, flavonoids, carotenoids, vitamin C, and dietary fiber. This study aimed to valorize tomato processing waste into functional powder and evaluate the fate and antioxidant activity of bioactive compounds during simulated gastrointestinal digestion. Functional powders were developed using different formulations and analyzed for physicochemical, structural, and functional properties. In vitro digestion was performed under oral, gastric, and intestinal phases to determine the stability and bioaccessibility of bioactive compounds. The results revealed significant variations among the developed powders. SP2 showed the highest lycopene content (7.70 ± 0.87 mg/100 g), total carotenoid content (59.07 ± 0.59 mg/100 g), total phenolic content (4.51 ± 0.06 mg GAE/g), and DPPH antioxidant activity. SP3 exhibited the highest vitamin C content (44.71 ± 0.33 mg/100 g) and total flavonoid content (38.02 ± 0.87 mg QE/100 g), while SP1 demonstrated comparatively lower bioactive retention. Simulated digestion significantly influenced the release and transformation of bioactive compounds. Phenolic and flavonoid contents increased during intestinal digestion due to improved release from the food matrix, whereas lycopene content decreased during gastric digestion because of acidic degradation. SEM analysis revealed structural modifications and particle breakdown after digestion, supporting enhanced compound release. FRAP and DPPH assays confirmed increased antioxidant activity during the intestinal phase. Overall, the study demonstrated that tomato processing waste can be effectively converted into functional powders with enhanced bioaccessibility and antioxidant potential, supporting sustainable waste valorization and functional food applications.

INTRODUCTIONS

The tomato processing industry generates large quantities of waste, mainly peels and seeds, which are commonly discarded despite being rich in valuable bioactive compounds such as lycopene, polyphenols, and flavonoids.

Most existing utilization approaches focus primarily on converting tomato processing waste into powders or food ingredients, while limited attention is given to the stability and release of these bioactive compounds during human digestion.

The health benefits of tomato-waste-derived powders depend not only on the amount of bioactive compounds present but also on their bioaccessibility and antioxidant activity after oral, gastric, and intestinal digestion phases.

RESEARCH GAPS

Previous studies mainly emphasized the production, physicochemical properties, and antioxidant composition of tomato waste powders, with limited investigation into the fate of bioactive compounds during gastrointestinal digestion.

Comparative information on how different powder formulations and stabilizers influence the release, retention, and bioavailability of antioxidants during digestion remains insufficient.

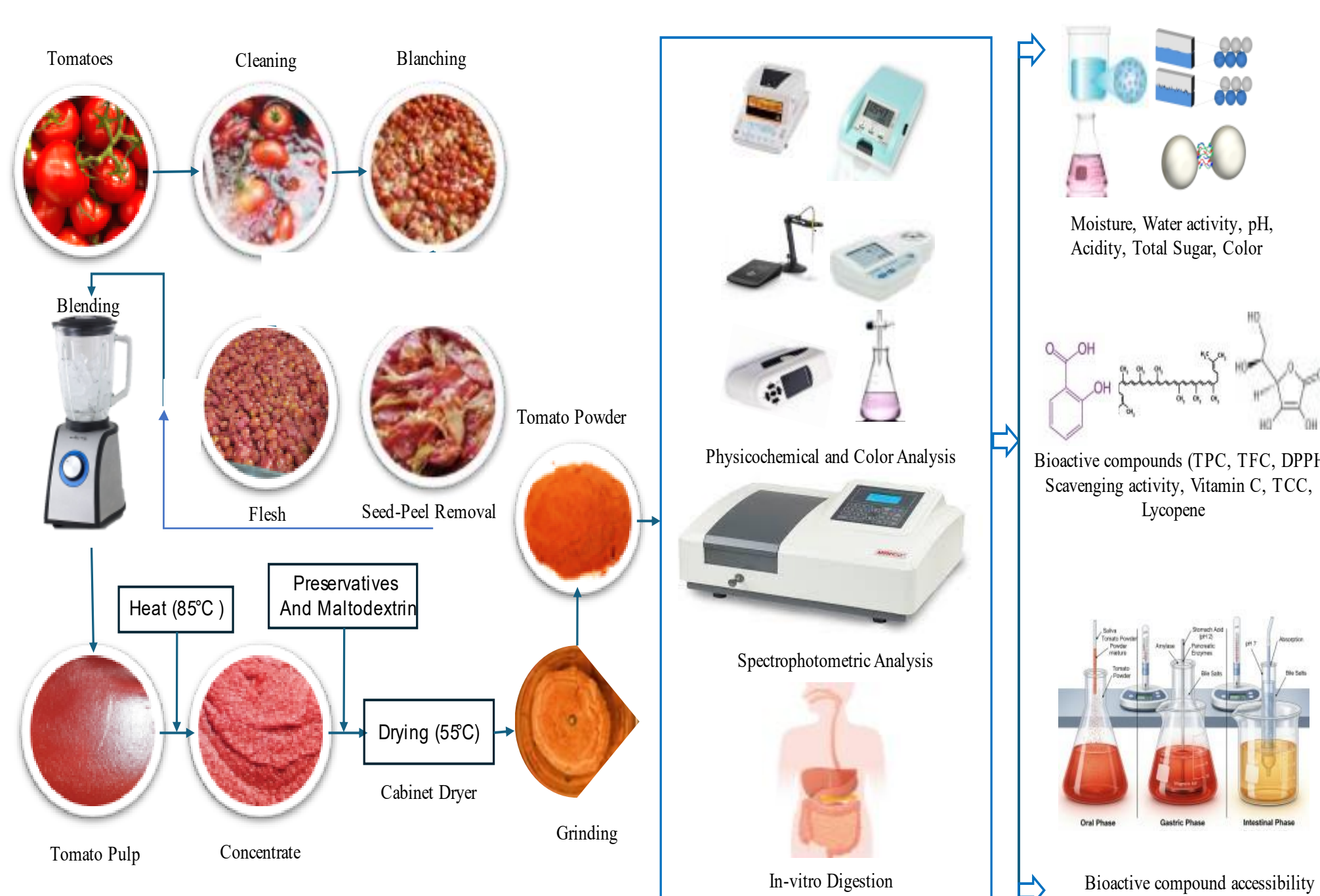
There is a lack of comprehensive studies linking drying/formulation methods with in vitro digestion behavior and antioxidant functionality of tomato peel and seed powders intended for functional food applications.

RESEARCH OBJECTIVES

To develop functional powders from tomato processing waste (peels and seeds) using different formulation approaches and evaluate their physicochemical and antioxidant properties.

To investigate the fate, stability, and bioaccessibility of bioactive compounds and antioxidant activity of the developed powders during simulated oral, gastric, and intestinal digestion.

Methodology



RESULTS

Table 1: Effects of Preservatives and Maltodextrin on the Physicochemical Properties of Tomato Waste Powder

Sample Name	Moisture (%)	Water Activity	pH	Acidity (%)	Color		
					L*	a*	b*
SP1	7.00 ± 0.24 ^a	0.363 ± 0.00 ^a	4.55 ± 0.03 ^a	0.28 ± 0.01 ^b	61.10 ± 0.03 ^b	23.31 ± 0.05 ^b	54.51 ± 0.16 ^a
SP2	7.70 ± 0.87 ^a	0.385 ± 0.01 ^b	4.51 ± 0.06 ^a	0.32 ± 0.00 ^a	59.07 ± 0.59 ^c	24.32 ± 0.30 ^a	53.80 ± 0.73 ^a
SP3	5.15 ± 0.13 ^b	0.438 ± 0.01 ^a	4.59 ± 0.02 ^a	0.16 ± 0.00 ^c	67.24 ± 0.18 ^a	22.12 ± 0.08 ^c	50.50 ± 0.30 ^b

All results showed as Mean±STDEV. a-b different letter indicated the significant difference among the samples at 5% significance level. Here, SP1=Tomato Powder Produced from Tomato Waste using Preservatives, SP2=Tomato Powder Produced from Tomato Waste using Preservatives with maltodextrin, SP3= Control Sample

Table 2: Effects of Preservatives and Maltodextrin on the Powder Properties of Tomato Waste Powder

Sample Name	Bulk density (g/cm ³)	Tap density (g/cm ³)	Water absorption index (g H ₂ O/g)	Water solubility index (%)	Carr's Index (%)
SP1	0.34 ± 0.02 ^b	0.509 ± 0.009 ^b	4.29 ± 0.08 ^a	17.88 ± 0.59 ^c	32.76 ± 4.19 ^b
SP2	0.32 ± 0.00 ^c	0.484 ± 0.001 ^c	4.20 ± 0.06 ^a	19.26 ± 0.42 ^b	34.73 ± 0.69 ^{ab}
SP3	0.42 ± 0.01 ^a	0.682 ± 0.001 ^a	3.37 ± 0.05 ^b	44.71 ± 0.33 ^a	38.02 ± 0.87 ^a

All results showed as Mean±STDEV. a-b different letter indicated the significant difference among the samples at 5% significance level. Here, SP1=Tomato Powder Produced from Tomato Waste using Preservatives, SP2=Tomato Powder Produced from Tomato Waste using Preservatives with maltodextrin, SP3= Control Sample

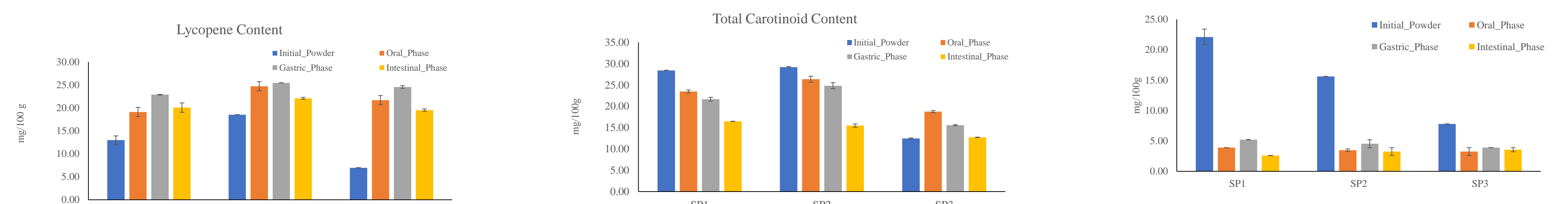


Figure 1: Effects of Preservatives and Maltodextrin on Lycopene, Carotenoid and Vitamin C content the Powder Properties of Tomato Waste Powder During In vitro Digestion

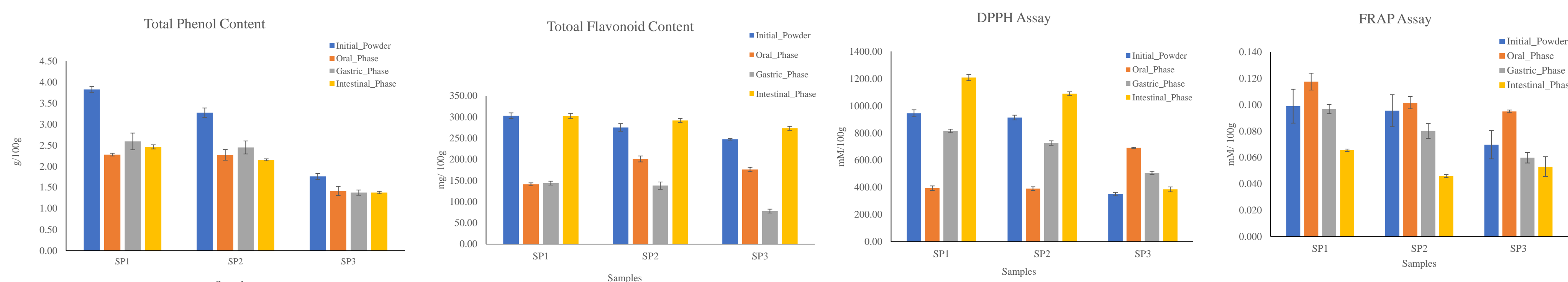


Figure 2: Effects of Preservatives and Maltodextrin on Antioxidant and Antioxidant activity of Powder Properties of Tomato Waste Powder During In vitro Digestion

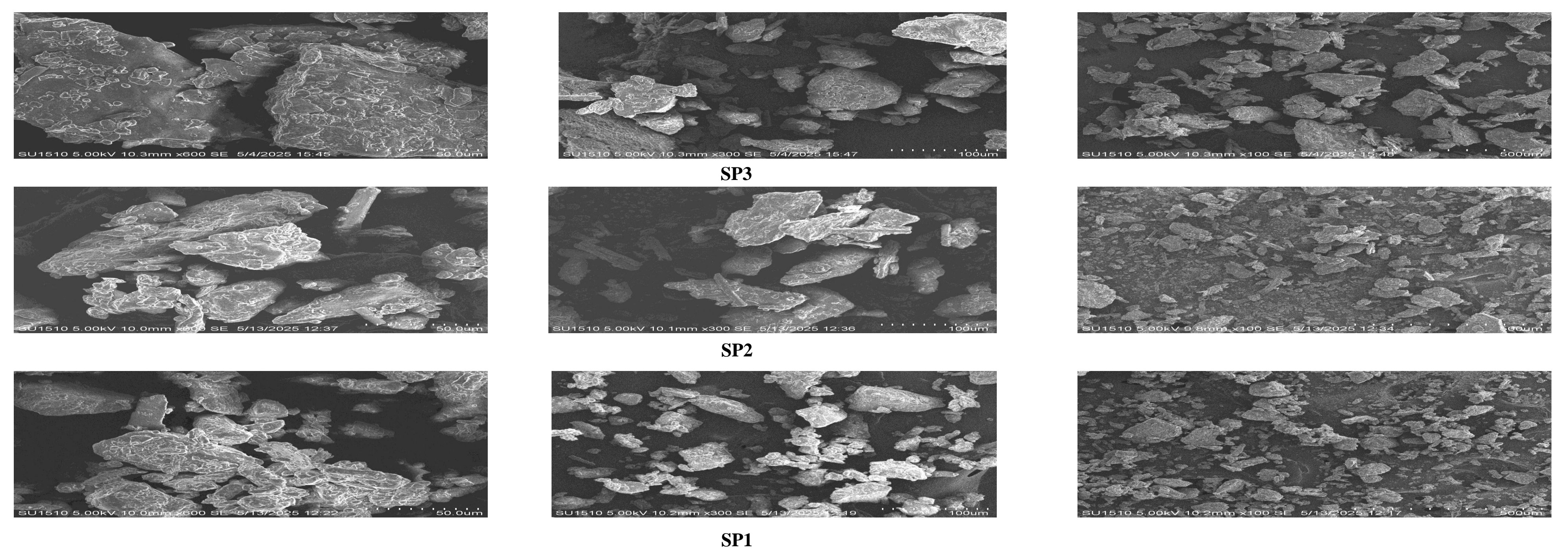


Fig 4. Scanning electron microscope of tomato waste powder

Here, SP1=Tomato Powder Produced from Tomato Waste using Preservatives, SP2=Tomato Powder Produced from Tomato Waste using Preservatives with maltodextrin, SP3= Control Sample

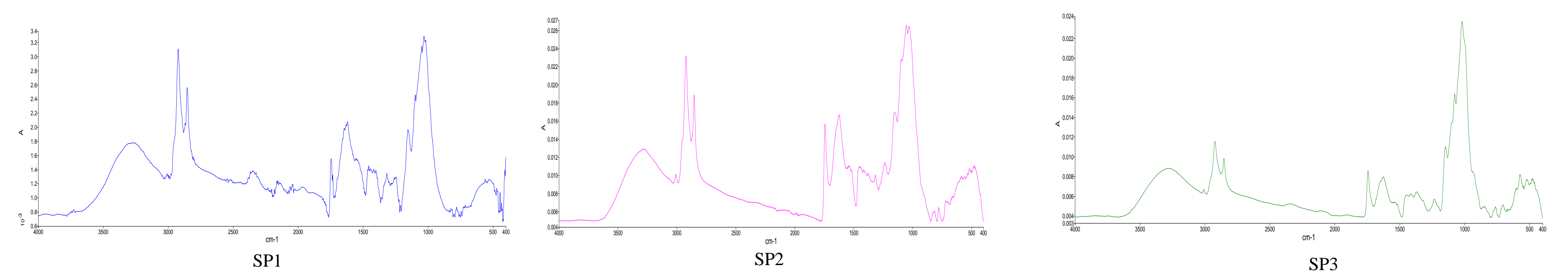


Fig.5: FTIR analysis of Tomato Waste Powder

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CONCLUSION

- Tomato processing waste, especially peels and seeds, can be effectively utilized to develop functional powder instead of being discarded, supporting waste valorization and sustainable food production.
- The developed tomato waste powders contained valuable bioactive compounds and antioxidant properties, but their effectiveness depended not only on their initial composition but also on their stability and release during digestion.
- Simulated oral, gastric, and intestinal digestion showed that the fate, bioaccessibility, and antioxidant activity of bioactive compounds changed across digestion phases. Therefore, tomato peel and seed powders have strong potential as functional food ingredients

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