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## How to ensure the printability of a food matrix? From formulation to consumer appreciation.

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## INTRODUCTION

3D food printing allows the development of personalized, appealing and healthy foods through different shapes, textures, nutritional compositions and tastes. A printable wheat flour based dough can be obtained by applying a thermomechanical treatment<sup>1,2</sup>. This work presents a multidisciplinary approach by understanding the impact of addition fruit/vegetable purees on the rheological properties and print quality of printing dough, determining the optimal printing parameters and 3D shape and then by validating printed and baked products by consumers.

## OBJECTIVES

The main objective was to determine **print quality criteria** independent of the formulation to diversify printable food matrix.

Criteria under study covered the following properties of printed products:

- Rheological (rheometer)
- Textural (texture analyser)
- Dimensional (image analysis)

**Print quality criteria**



	Relevance	Target
n	⊘	Depends on formulation
K	✓	max 500 Pa.s <sup>n</sup>
G'	⊘	Depends on formulation
G''	⊘	Depends on formulation
Tanδ	✓	0,15-0,16

Based on shear flow and oscillatory measurements, 2 rheological criteria were found to describe the printing quality.

**Formulation**

Formulation with constant wheat flour content

30% Wheat flour  
+ X % Fruit or veg  
+ (70 - X)% Water

**Control**  
0%

✓ Good printability  
✓ Shape is retained

**Addition of fruit or veg purees**

	Apple	Mango	Brocoli
20%			
70%			

**Addition of fruit or veg sera**

	Apple	Mango	Brocoli
35%			
70%			

All the formulation were successfully printed. However, the addition of fruit or vegetable purees and sera modifies the printing quality due to their physico-chemical properties (pH, sugar content, presence of soluble pectins) and due to the presence of particles (fruits and veg cells in purees).

**Printing process**

Finding the best print settings for one formulation

Apple: model product at AgroParisTech JMP- analysis for the optimal conditions

Optimal printing conditions	
Nozzle diameter (mm)	2.5
Infill rate (%)	90
Printing speed (mm/s)	15

**Comparison of different shapes, same proportion of fruit puree**

	Apple 45% puree	Mango 45% puree	Brocoli 45% puree
Star			
Triangle			
Circle			

**Image Analysis**

Star: Height/Width for different purees

Puree	Height/Width
Apple 20%	~0.4
Apple 45%	~0.4
Mango 20%	~0.4
Mango 45%	~0.4
Broccoli 45%	~0.4
Broccoli 70%	~0.4

	Relevance	Target (Star)
Perimeter	⊘	114 mm
Area	⊘	630 mm <sup>2</sup>
Width	⊕	42 mm
Height	⊕	15 mm
Height/Width	✓	0.36

The star-shaped samples showed (visually) the lowest print quality, mainly for broccoli. The best parameter to quantify this result was the aspect ratio.

**Consumer validation**

Diversification of flour and addition of 20 % apple puree

Flour	0%	20%
Wheat T55		
Soy		
Rye T170		

Validation of the post-print baking (175°C, 17 min) for the addition of 20 % apple puree to wheat flour dough and for others flours by optimizing their process (water content and heating time / not shown here) to ensure printability.

**Preference Mapping based on the general appreciation of products by consumers**

Based on the ideal values for each sensory descriptors and using a desirability function, we determined that consumers preferred wheat flour products with 7 % of apple puree.

	Relevance	Target
Mean force	⊕	> 20 N < 40 N
Height	✓	> 15 mm
Width	✓	30 mm

The mean force of the dough and the dimensional profile of the 3D-printed products were used to optimize the printing quality of each dough but mean force depends on formulation.

## ACKNOWLEDGMENTS



## REFERENCES

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## CONCLUSION

- Rheological properties** K and Tanδ are good print quality criteria and are independent of the formulation.
- Textural properties** such as mean force define a printability range but this criterion must be further studied since it depend on the formulation.
- Dimensional measurements** are good print quality criteria especially the ratio height/width. Image analysis must be thorough.