Orange peels as a second-generation feedstuff to produce a new feed ingredient for dairy sheep

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Orange peel-based ingredients for dairy sheep

SEVT is responsible for the provision of the orange peels

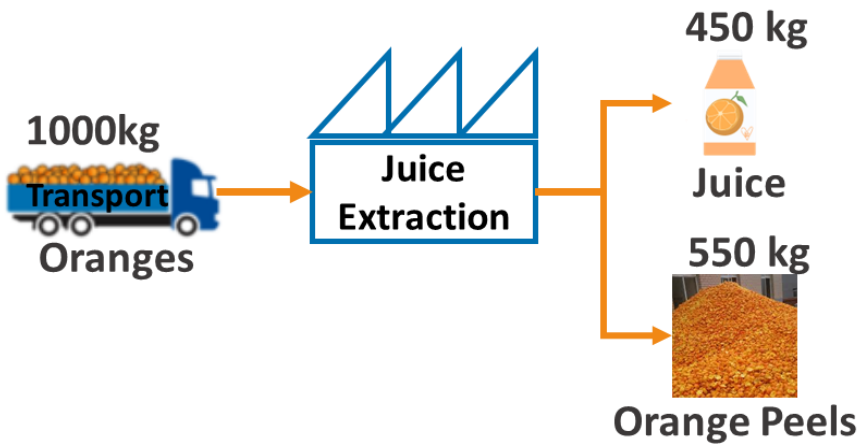
NTUA optimized the valorization strategy, scaled up the entire process and produced the ingredients for the animal feed demonstrative actions

ELGO determined the Feeding Strategy based on the analysis of the obtained ingredients and performed the animal feed demonstrative actions

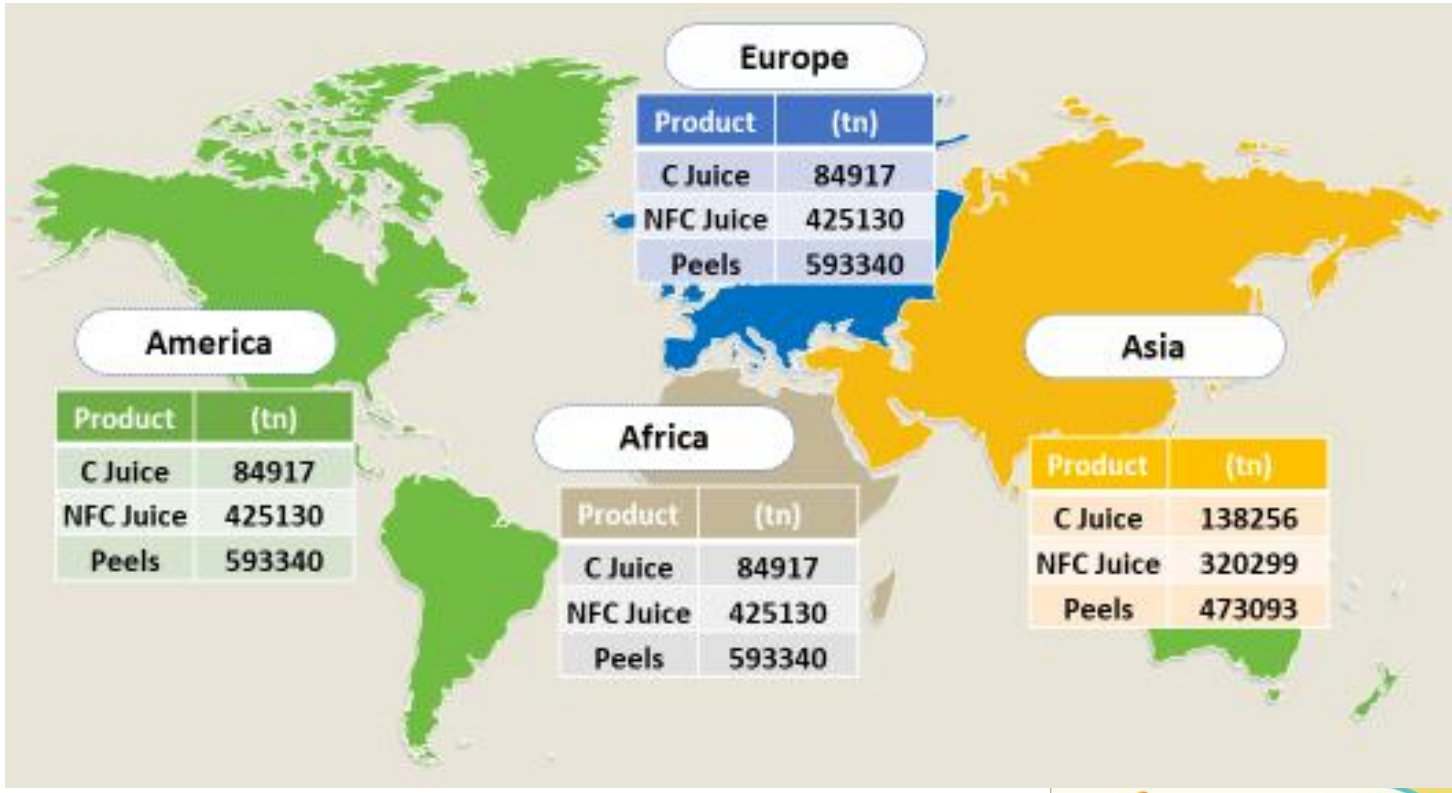
UOWM performed the quality, nutritional value and sensory analysis of food resulting products (milk and yoghurt).

Orange Peels Potential

Orange Juice Industry



Geographical distribution of annual production of orange juice production and resulting orange peels

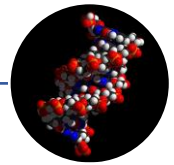


Current situation

Animal Feed

Food industry

Biofuels

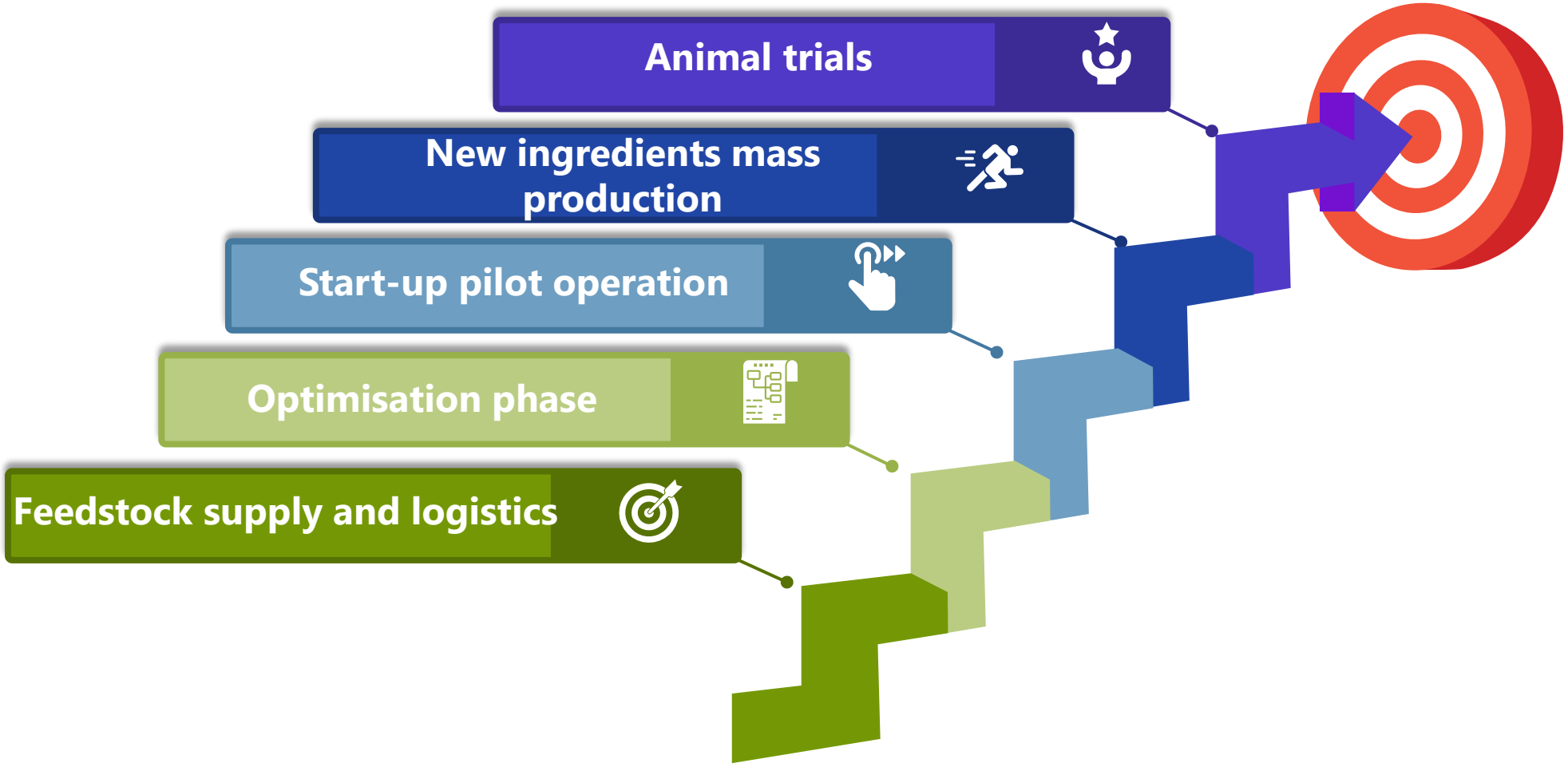


Biochemicals

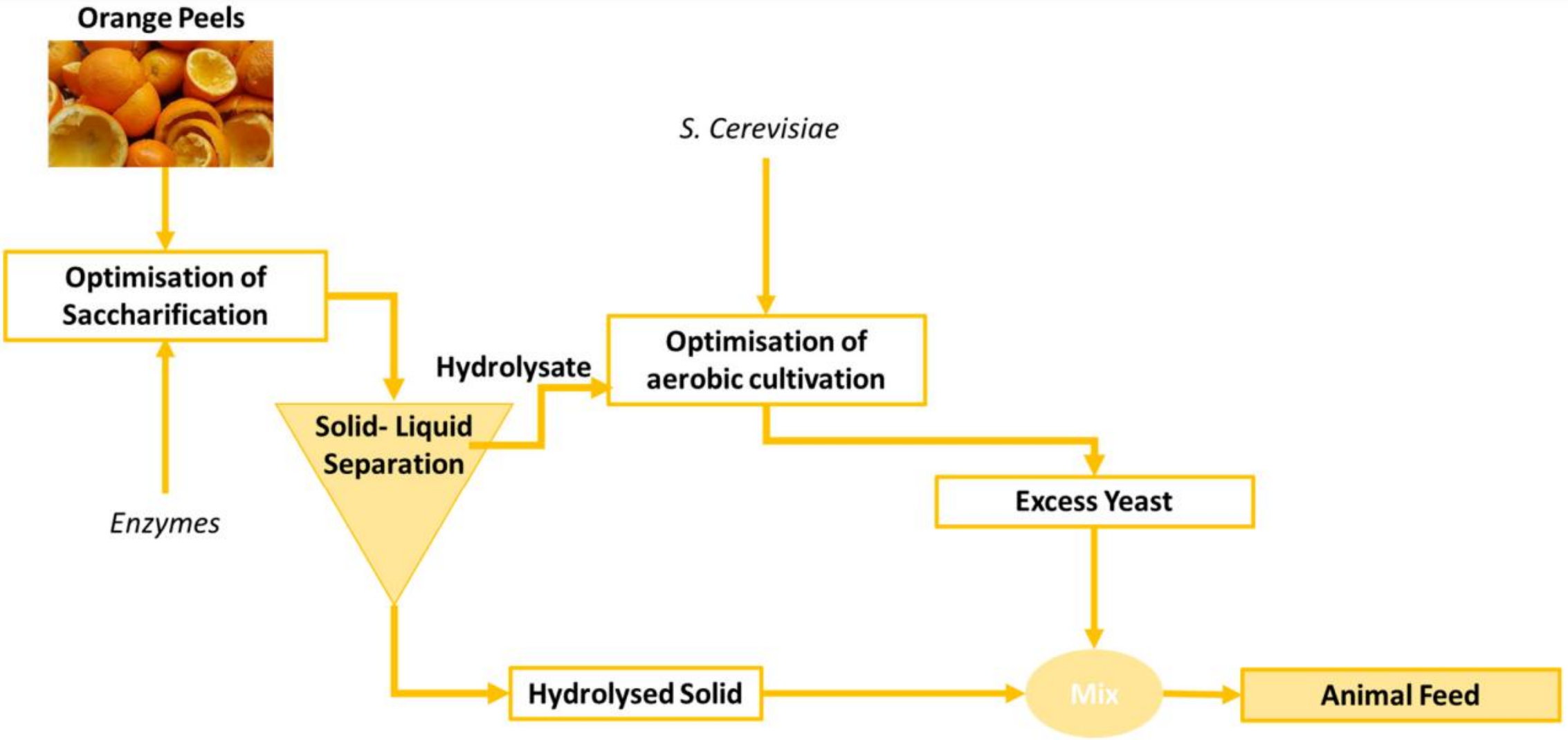
Essential oils

Other

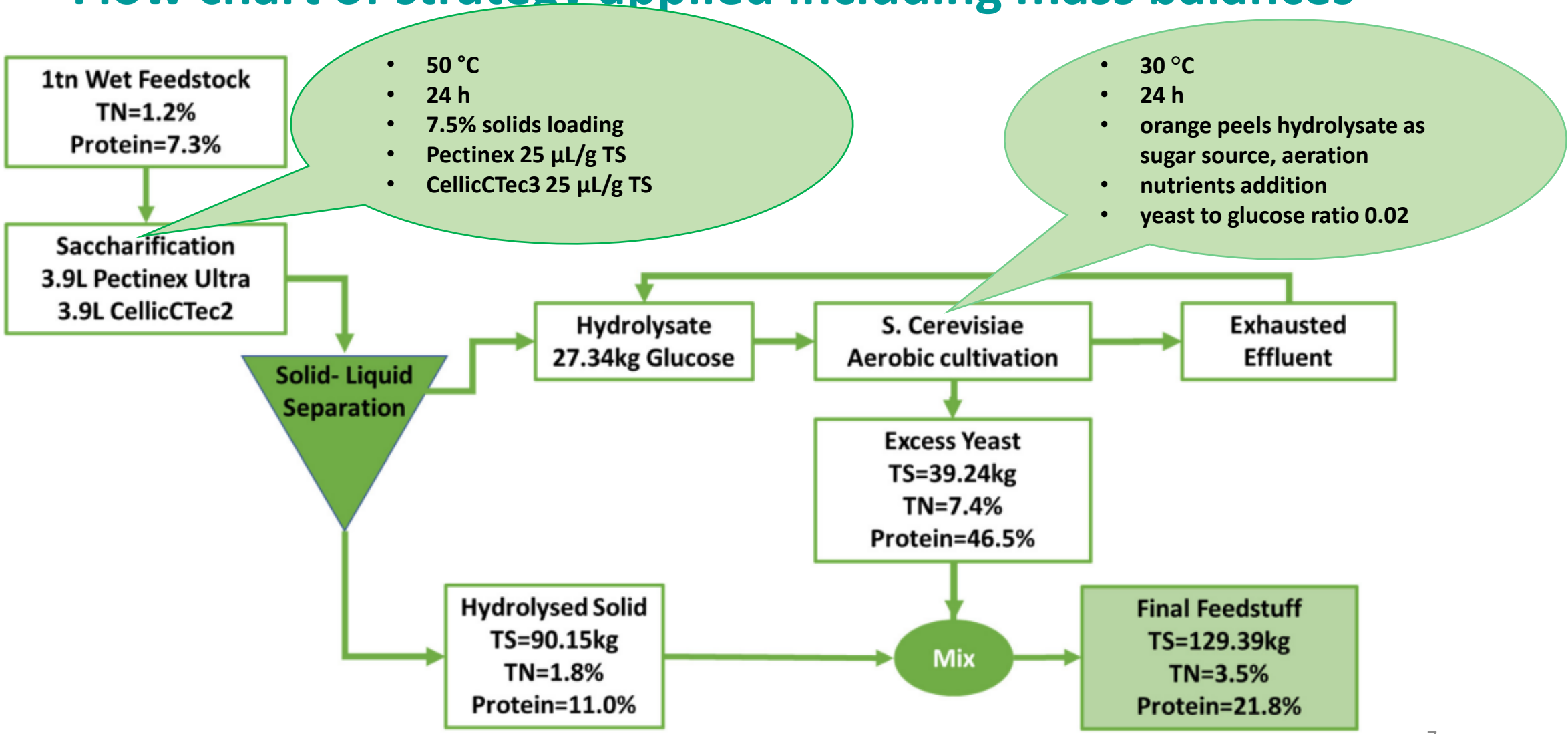
Workplan


Animal trials
New ingredients mass production
Start-up pilot operation
Optimisation phase
Feedstock supply and logistics

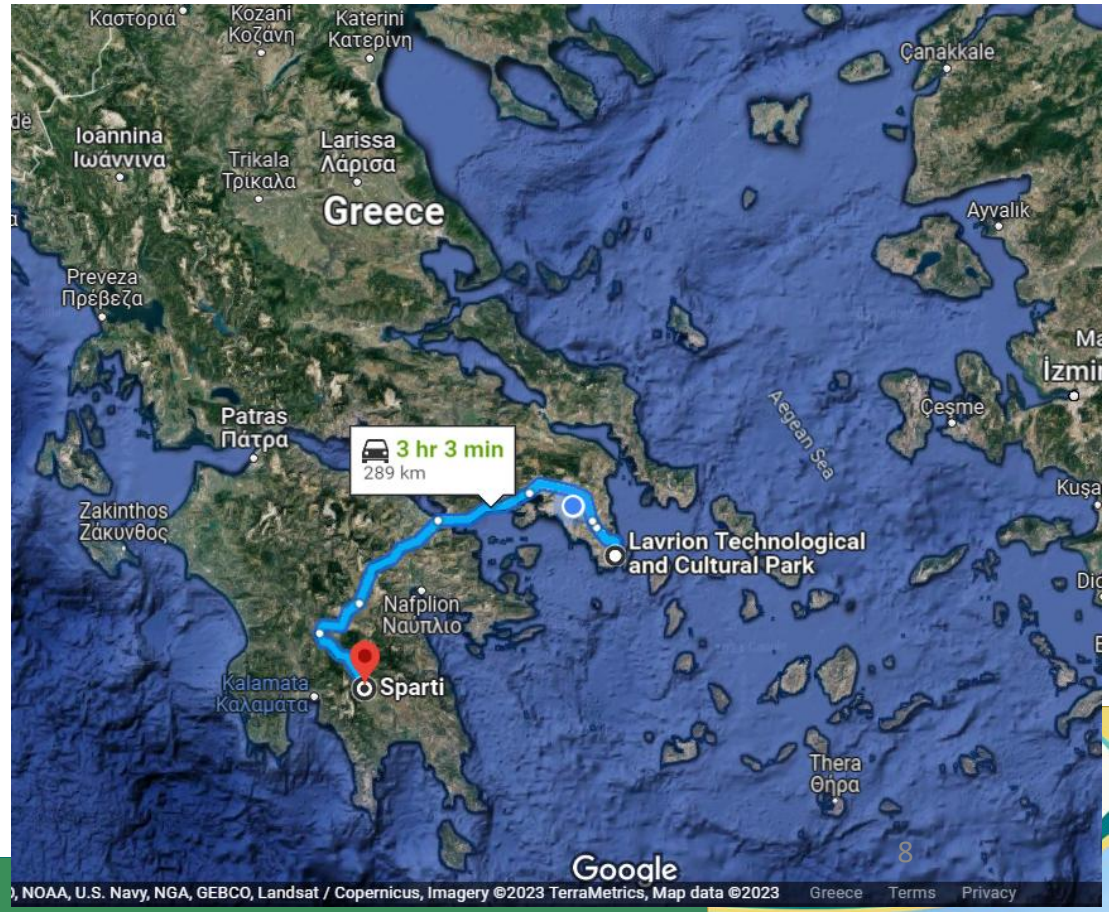
Orange Peels Valorisation Strategy



Flow chart of strategy applied including mass balances



Origin and transportation of orange peels



Infrastucture

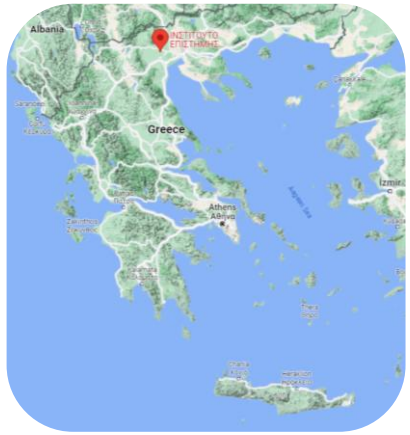
Operational module	Pilot scale (kg/d)	Demo scale (kg/d)
Bioconversion	75	375
Drying	50	1000

Composition of orange peel-based ingredients for dairy sheep

Parameter	Unprocessed orange peels	Processed orange peels
Total Solids	91.85±1.65	93.34±1.92
Moisture	8.15±1.65	6.66±1.92
Volatile Solids (% d.b.)	91.35±1.78	92.83±2.01
Ash (% d.b.)	8.65±1.78	7.17±2.01
Oils (% d.b.)	0.25±0.01	0.32±0.03
Water Soluble Solids (% d.b.)	35.99±1.98	36.85±2.21
Cellulose (% d.b.)	17.47±2.12	15.51±1.78
Hemicellulose (% d.b.)	30.70±4.46	23.34±3.41
Acid Soluble Lignin (% d.b.)	1.06±0.08	0.81±0.03
Acid Insoluble Lignin (% d.b.)	10.70±1.11	12.36±0.98
TN (% d.b.)	1.38±0.04	3.66±0.07
Crude protein (%d.b..)	8.63±2.39	22.88±2.43
NDF (% d.b.)	34.10±3.21	26.74±3.42
ADF (% d.b.)	24.80±3.43	23.81±3.87
ADL (% d.b.)	6.20±2.16	8.30±2.01
NDIN (% d.b.)	0.47±0.01	0.29±0.02
NDICP (% d.b.)	2.94±0.06	1.81±0.13
ADIN (% d.b.)	0.12±0.06	0.06±0.03
ADICP (% d.b.)	0.75±0.38	0.38±0.19
IVOMD (% d.b)	69.20±0.99	81.6 ± 1.13

Experimental Design & Animal Feeding

Sheep farm of the Research Institute of Animal Science of HAO-Dimitra



Experimental Ration Composition

Formulation of *isonitrogenous* and *isoenergetic* diets by substituting conventional feed ingredients and by meeting the nutrient requirements

	Diet		
Ration composition	**Control**	**EMA**	**EMB**
Corn grain	300	300	300
Barley grain	200	200	200
Wheat grain	200	120	120
Soyabean meal	110	110	110
Sunflower meal	150	120	120
Experimental feedstuff	0	110	110
Limescale	5	5	5
Monocalcium phosphate	5	5	5
Salt	5	5	5
Vitamin and mineral premix	25	25	25

Plus
1 kg of alfalfa hay
and 0.3 kg of straw per ewe/day

Feed efficiency animal trial

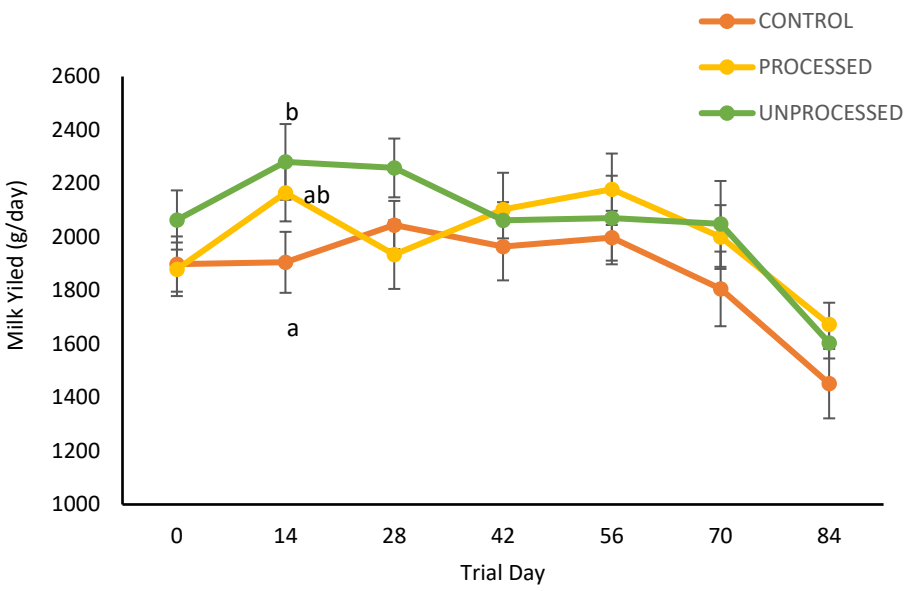
- ✓ Allocation of ewes in 3 groups of 12 (control, experimental material A, experimental material B)
- ✓ Housed in separate floor pens and fed individually for a period of 84 days
- ✓ Starting on the day after weaning until the 16th week of lactation
- ✓ Evening and morning milk production calculation and allocation in groups according to production, lactation and days in milk

Recorded parameters:

- Daily milk yield
- Chemical composition and total bacterial count of individual milk samples
- Daily feed intake and refusals
- Environmental indices
- Health and welfare
- Rumen fluid
- Life cycle analysis data

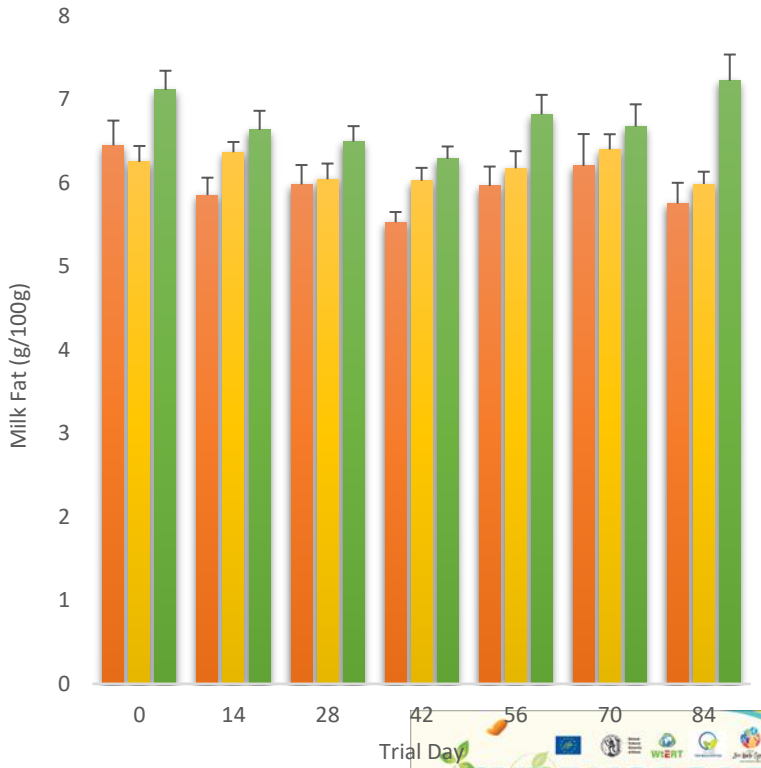
Fat corrected average milk yield

- ✓Significant difference (p<0.05) between Control and Unprocessed at the 2nd sampling (day 14 of the trial)
- ✓Unprocessed group had higher milk yield on average(2055.45 ± 115.327 gr), until the middle of the trial, when the Processed group reached, and surpassed its' milk yield (1990.46 ± 115.110 gr)
- ✓The Control group remained steady throughout the trial at lower levels (1866.96 ± 114.781gr)



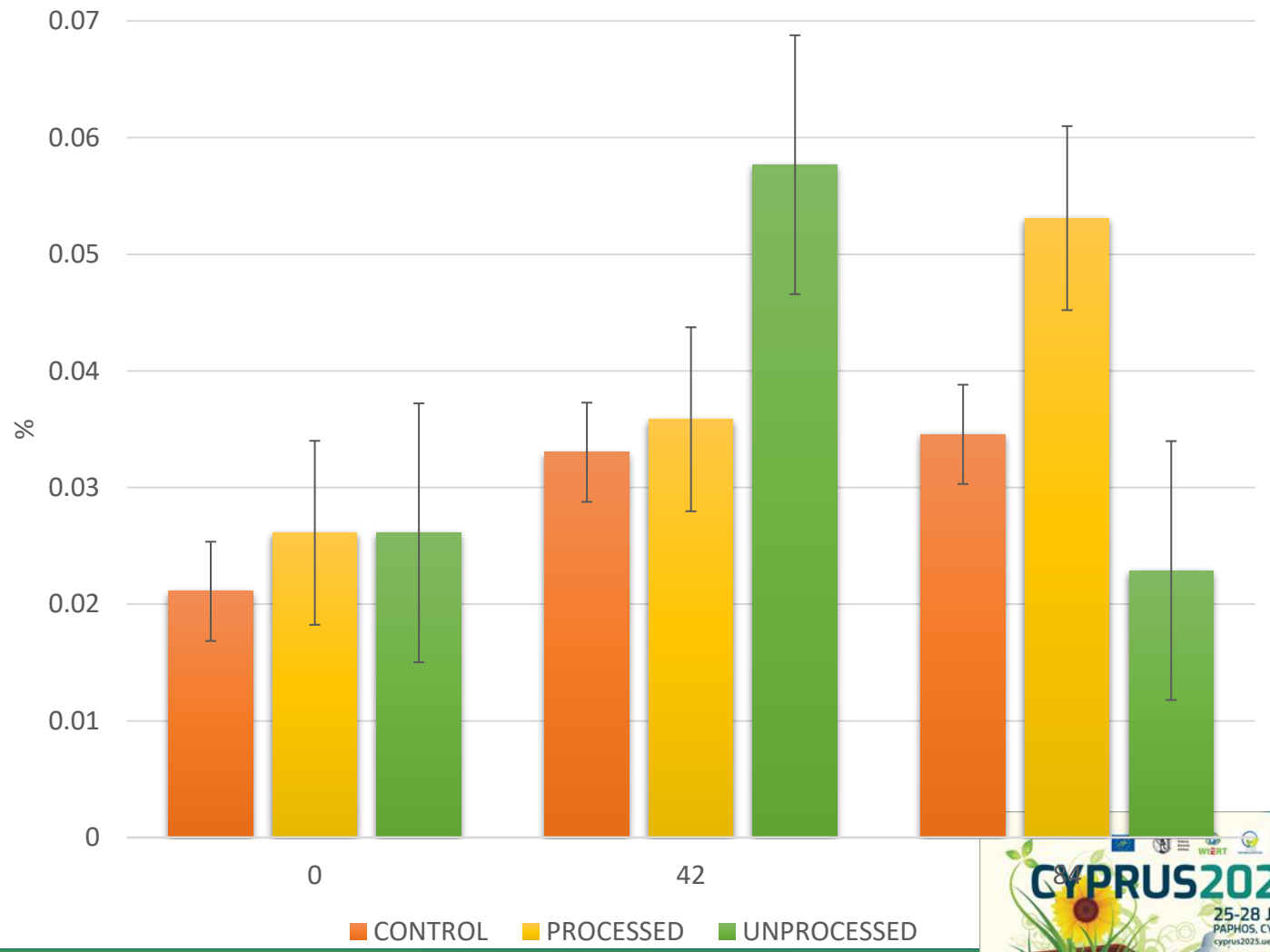
Mean milk fat content

- ✓ At the majority of the samplings milk fat concentration in the Unprocessed treatment was significantly higher than in the Control group (6.75 ± 0.229 vs 5.96 ± 0.246 g/100g, p<0.05)
- ✓ Milk fat concentration in the Processed treatment (6.17 ± 0.170 vs 5.96 ± 0.246 g/100g) was higher compared to the Control group, although not statistically significant



Relative abundance of methanogenic bacteria in the rumen

- ✓ The relative abundance of methanogens was overall higher in the experimental groups, compared to the controls, in all samplings
- ✓ Data were not evaluated statistically due to a low aboundance of archaea in the samples (0.046% of the total reads), although methanogens accounted for 76.15% of the archaea
- ✓ The steep reduction of the methanogens at the end of the trial in the unprocessed group, could be attributed to the tannin content of the feed, as well as to an undocumented property of orange as a potent inhibitor of the enzyme hydroxyl methyl glutaryl coenzyme A (HMG-CoA) reductase which catalyses the synthesis of units essential for cell membrane stability



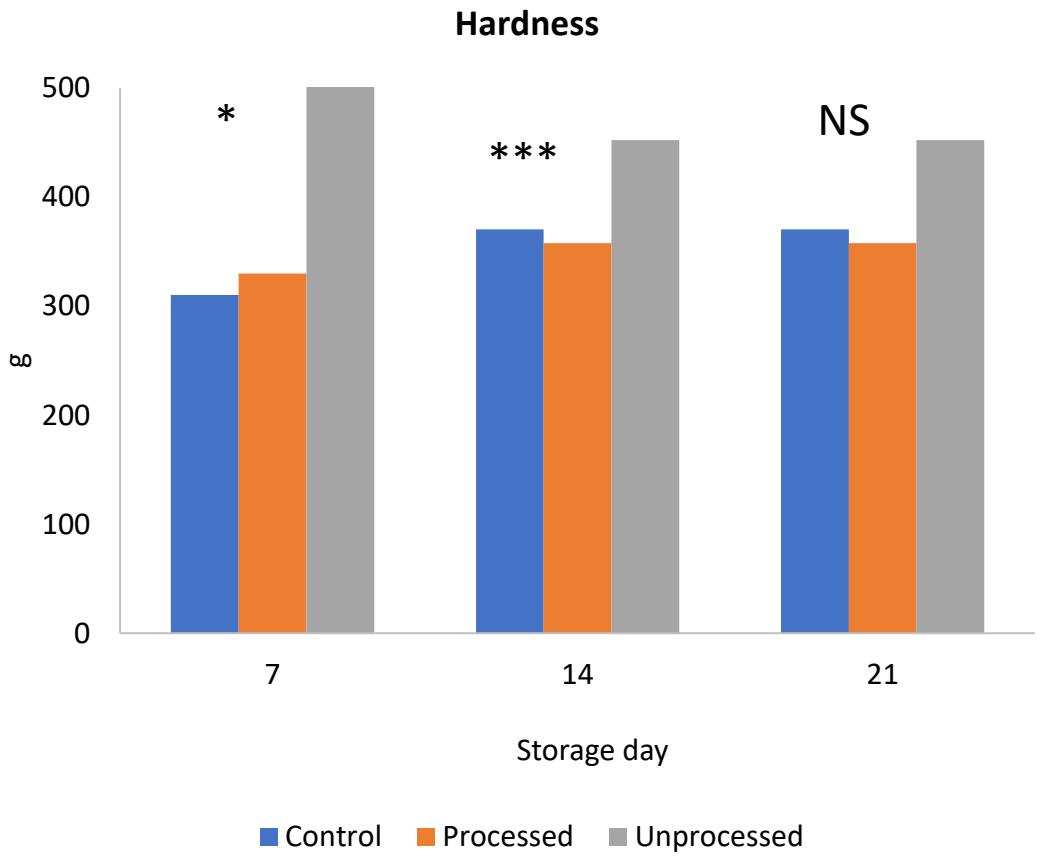
Yoghurt Chemical Composition

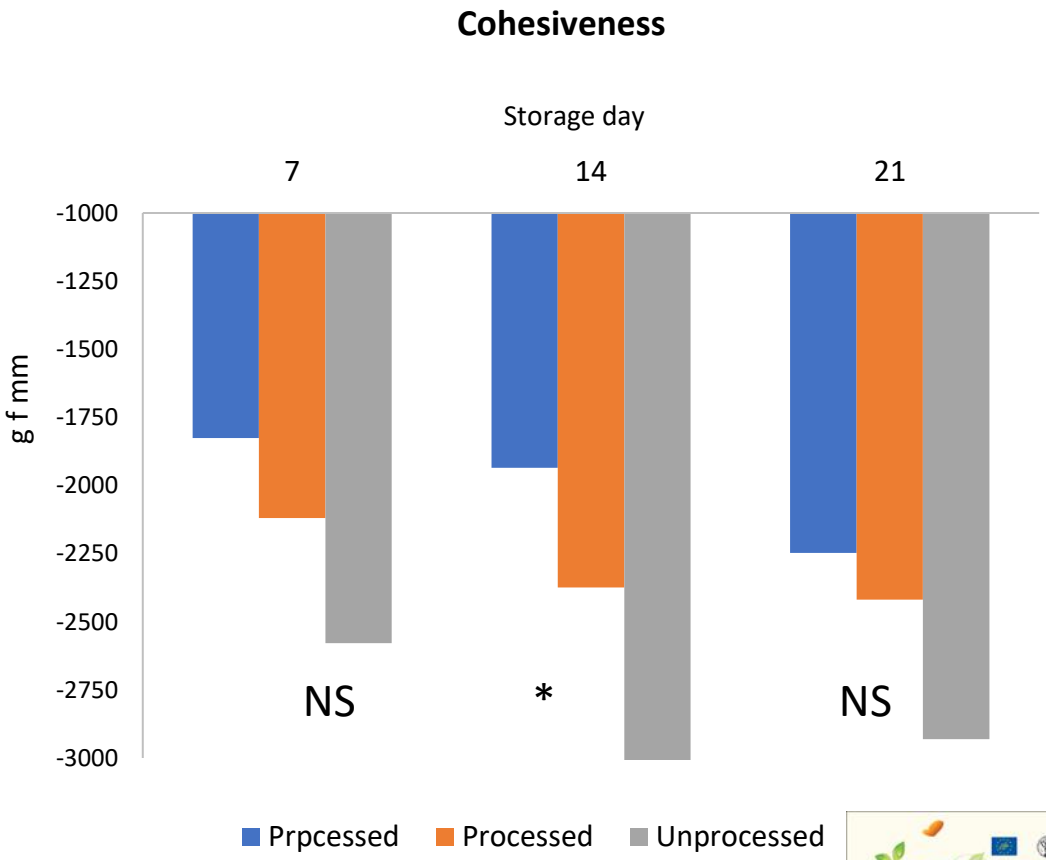
Treatment	Moisture (g/100 g)	Ash (g/100 g)	Protein (g/100 g)	Fat (g/100 g)	Carbohydrates (Sugars) (g/100 g)
Control	83.39	0.81	5.42	6.06	4.32
Processed orange peels	82.76	0.88	5.53	6.24	4.60
Unprocessed orange peels	82.32	0.89	5.93	6.79	4.06
Significance	**	*	*	*	NS

Yoghurt Fatty Acid Composition – Nutritional Profile

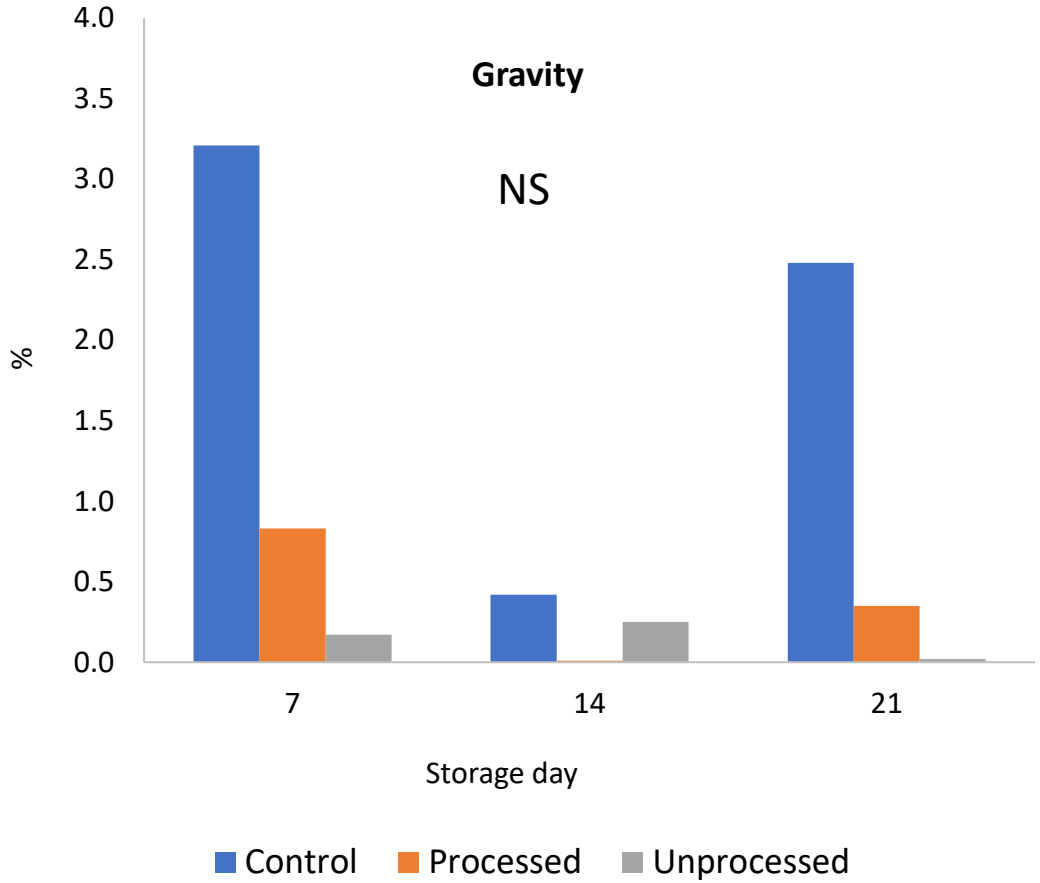
Parameter	Control	Processed orange peels	Unprocessed orange peels	Significance
Lipid Class				
Saturated	72.99	72.84	73.74	NS
Monounsaturated	20.15	20.63	19.96	NS
Polyunsaturated	6.23	5.95	5.73	NS
n-3	0.99	0.99	0.95	NS
n-6	4.36	4.23	4.07	NS
Nutritional Index				
Atherogenicity index (AI)	3.56	3.44	3.74	NS
Thrombogenicity Index (TI)	3.28	3.25	3.45	NS
Ratio hypocholesterolemic: hypercholesterolemic (h/H)	0.47	0.49	0.45	NS
Polyunsaturated/ Saturated fatty acids ratio	0.09	0.08	0.08	NS

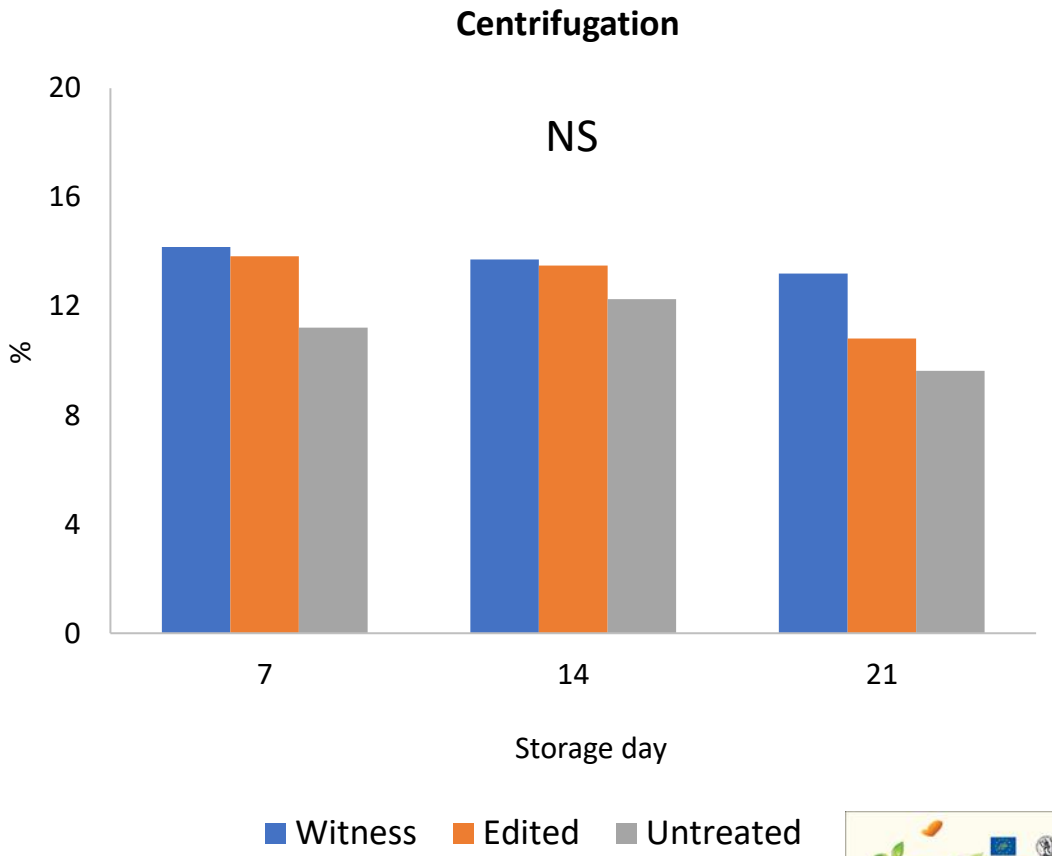
Yoghurt Texture - Changes During Storage



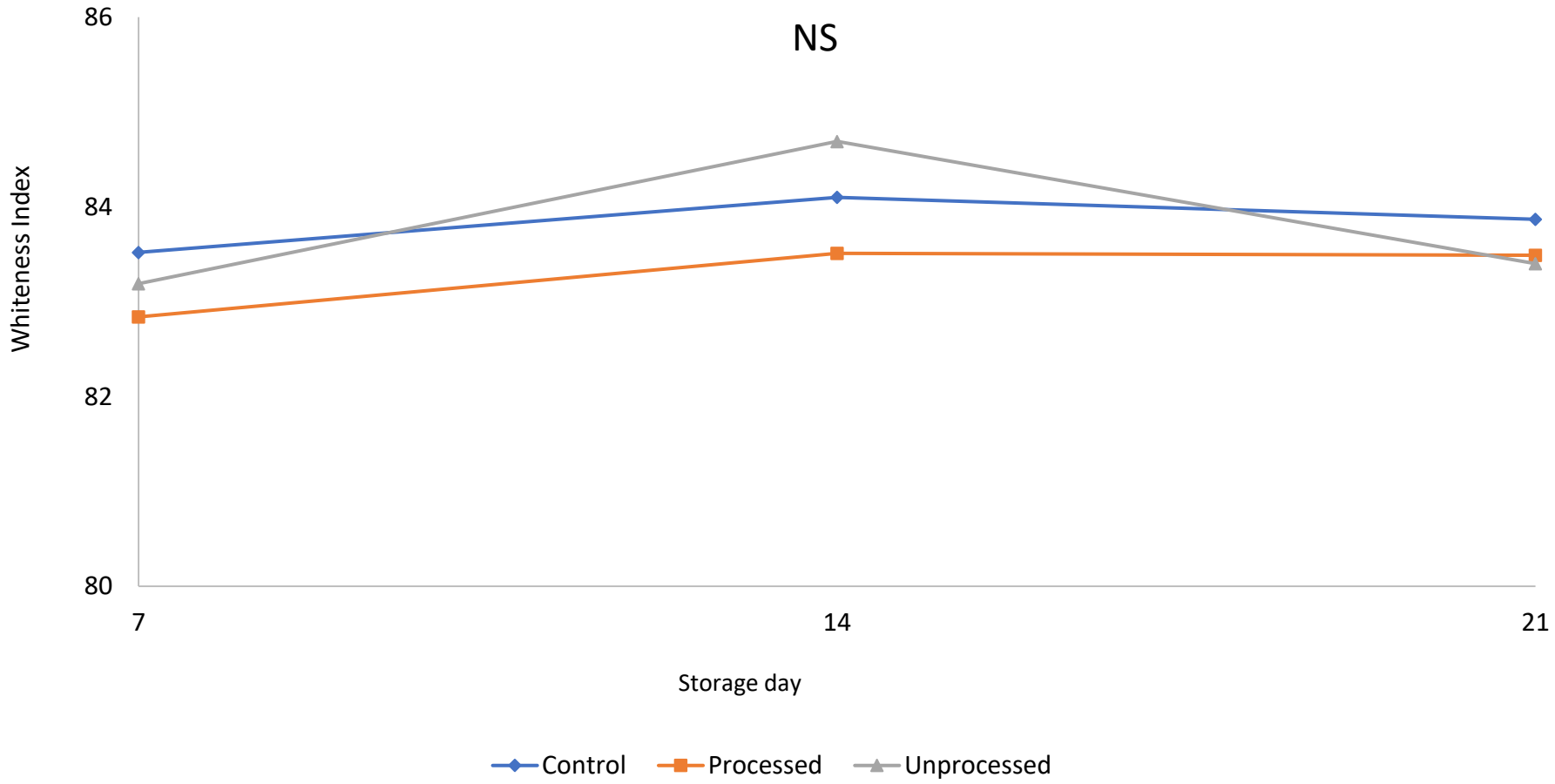


Yoghurt Syneresis - Changes During Storage

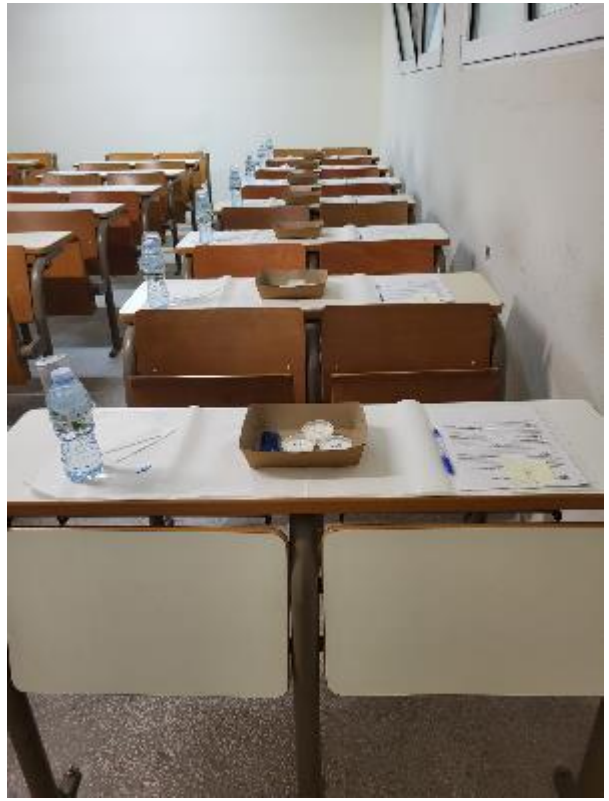




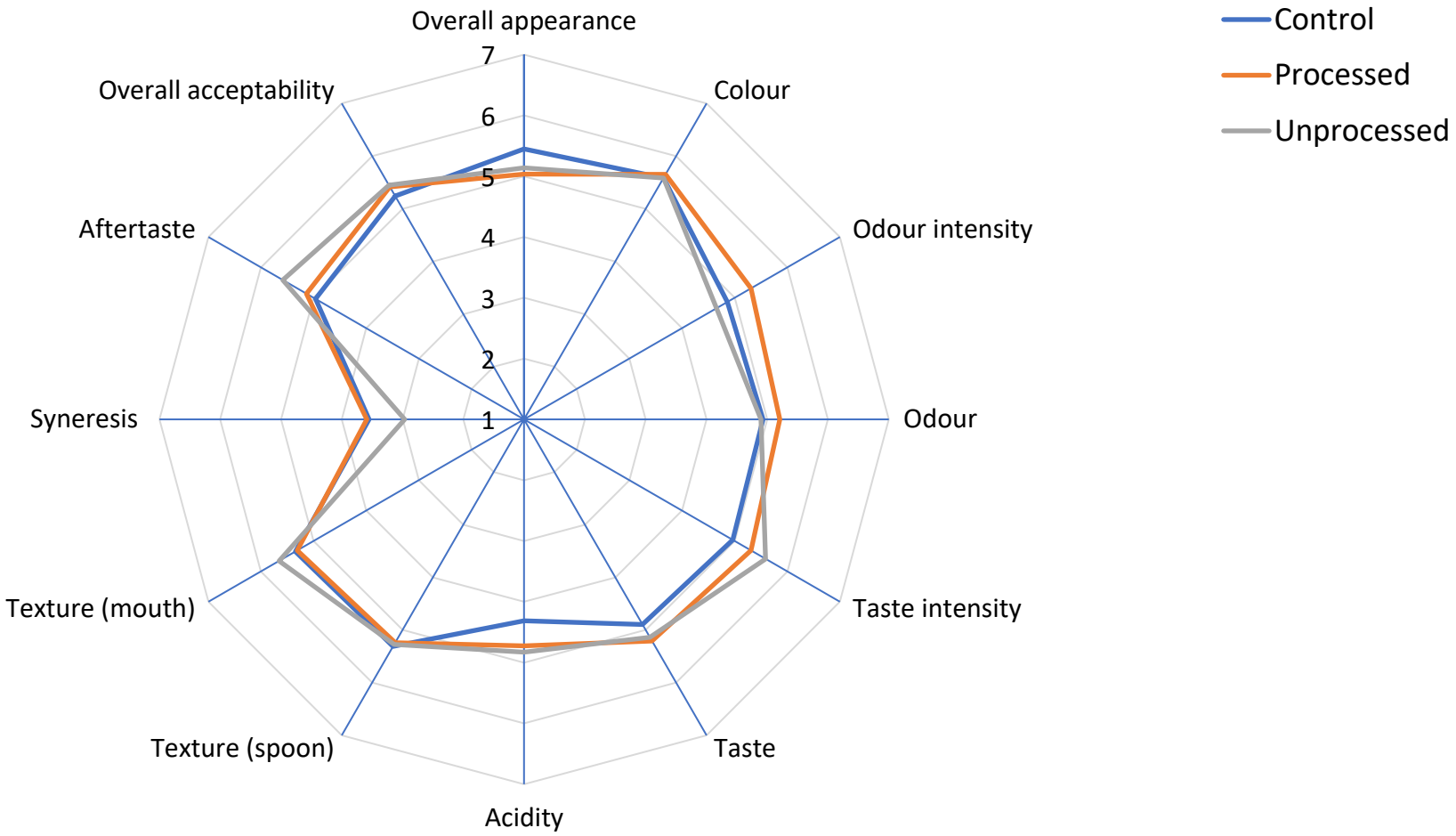
Yoghurt Whiteness Index - Changes During Storage



Yoghurt - Taste Panel



Yoghurt – Sensory Evaluation



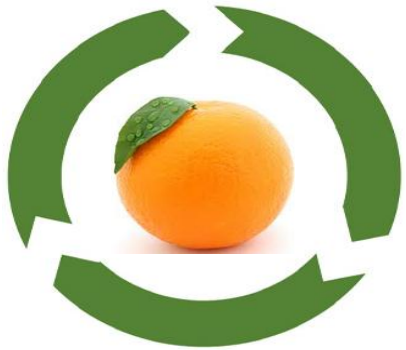
Conclusions – Case Study 2: Orange Peels as a Sustainable Feed Ingredient

🐑 **Animal Performance**

- ✔ Higher milk yield (UOP early, POP later)
- ✔ Improved feed efficiency
- ✔ Good animal health & welfare
- ✔ ↓ Methanogenic bacteria

🥛 **Milk & Yoghurt Quality**

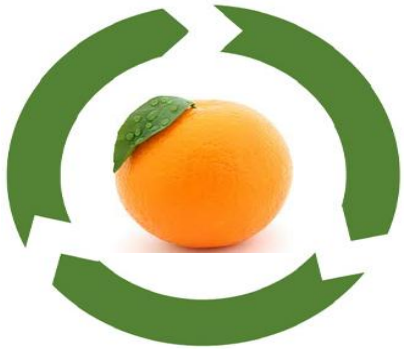
- ✔ ↑ Milk fat and protein content
- ✔ ↑ PUFA content in yoghurt
- ✔ High sensory acceptability
- ✔ Stable texture & appearance



Circular Economy Impact

- •Valorisation of agro-industrial waste
- •Sustainable livestock feeding solution
- •Technically feasible at pilot scale

Conclusions – Case Study 2: Orange Peels as a Sustainable Feed Ingredient



Key Takeaways

- Orange peels can be transformed into high-value, protein-enriched feed ingredients.
- Both processed and unprocessed forms improved milk yield, composition, and yoghurt quality.
- Feed trials confirmed safety, palatability, and efficiency in dairy sheep.
- Environmental co-benefits include reduced rumen methanogens and waste reuse.
- A viable circular economy model for the livestock sector.

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION
IN THE MEDITERRANEAN AREA

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