

APPLICATION OF SPOUTED BED TECHNOLOGY FOR GOAT MILK POWDER PRODUCTION



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INTRODUCTION

Goat milk production constitutes nowadays an economic activity of increasing importance since this milk is of high nutritional interest, providing high quality protein, fat, carbohydrate, vitamins and minerals. For human being, goat milk offers superior digestibility to cow milk due to the short and medium chain fatty acid content, the curd strength and the reduced level of α -s₁ casein. Moreover, since the fat globule size in goat milk is smaller than one in cow milk, it becomes beneficial for enzymatic activity. In addition, goat milk is a suitable alternative for the production of baby food formulae since many bio-active compounds presented in this milk (nucleotides, free amino acids and polyamines) are at similar levels to human milk. Three-fold significance of goat milk and its products in human nutrition have been stressed in the literature: (a) feeding more starving and malnourished people than from cow milk; (b) treating people afflicted with cow milk allergies and gastro-intestinal disorders and (c) filling the gastronomic needs of connoisseur consumers. This work is aimed at investigating the feasibility of producing goat milk powder in a spouted bed dryer with inert particles. This is one step of a non-conventional process route to be established in rural co-operatives, located in the northeast of Brazil. Goat milk powder produced in this low-cost process must firstly attend the demand of the local food industries that require it as an intermediate product to be used as a food-ingredient. In order to attend this purpose, two groups of variables have been analyzed, those related to powder operation production and those related to the powder produced quality. Using an experimental two-level full factorial design, the powder production efficiency has been calculated and analyzed to define the type of inert particles, the injector and the operating mode for producing goat milk powder in this low-cost dryer. The powder quality of goat milk produced in the spouted bed can be inferred by comparing its mainly physicochemical properties with those of goat milk powder produced industrially in the spray dryer. Results corroborate that the spouted bed technology is feasible to produce continuously goat milk powder with high quality.

METHODOLOGY

Table 1 Prefixed operational conditions to carry out tests

Operational variables	Settled values	
	Intermittent milk feed	Continuous milk feed
Inert load (kg)	2.5	2.5
Air flow rate ratio (Q/Q_{ms})	1.2	1.2
Inlet air temperature ($^{\circ}C$)	90	90
Volume of milk emulsion processed (ml)	500	500
Initial moisture content (w.b.)	0.87	0.87
Total processing time (min)	100	50
Time interval without feeding (min)	10 × 5	0
Time interval for feeding (min)	10 × 5	50

Table 2 Matrix of experiments

Test #	Inert particles	Emulsion injector	Emulsion feeding
1 and 1R	HDPE (-1)	Atomizer (-1)	Continuous (-1)
2 and 2R	PP (+1)	Atomizer (-1)	Continuous (-1)
3 and 3R	HDPE (-1)	Drop-injector (+1)	Continuous (-1)
4 and 4R	PP (+1)	Drop-injector (+1)	Continuous (-1)
5 and 5R	HDPE (-1)	Atomizer (-1)	Intermittent (+1)
6 and 6R	PP (+1)	Atomizer (-1)	Intermittent (+1)
7 and 7R	HDPE (-1)	Drop-injector (+1)	Intermittent (+1)
8 and 8R	PP (+1)	Drop-injector (+1)	Intermittent (+1)

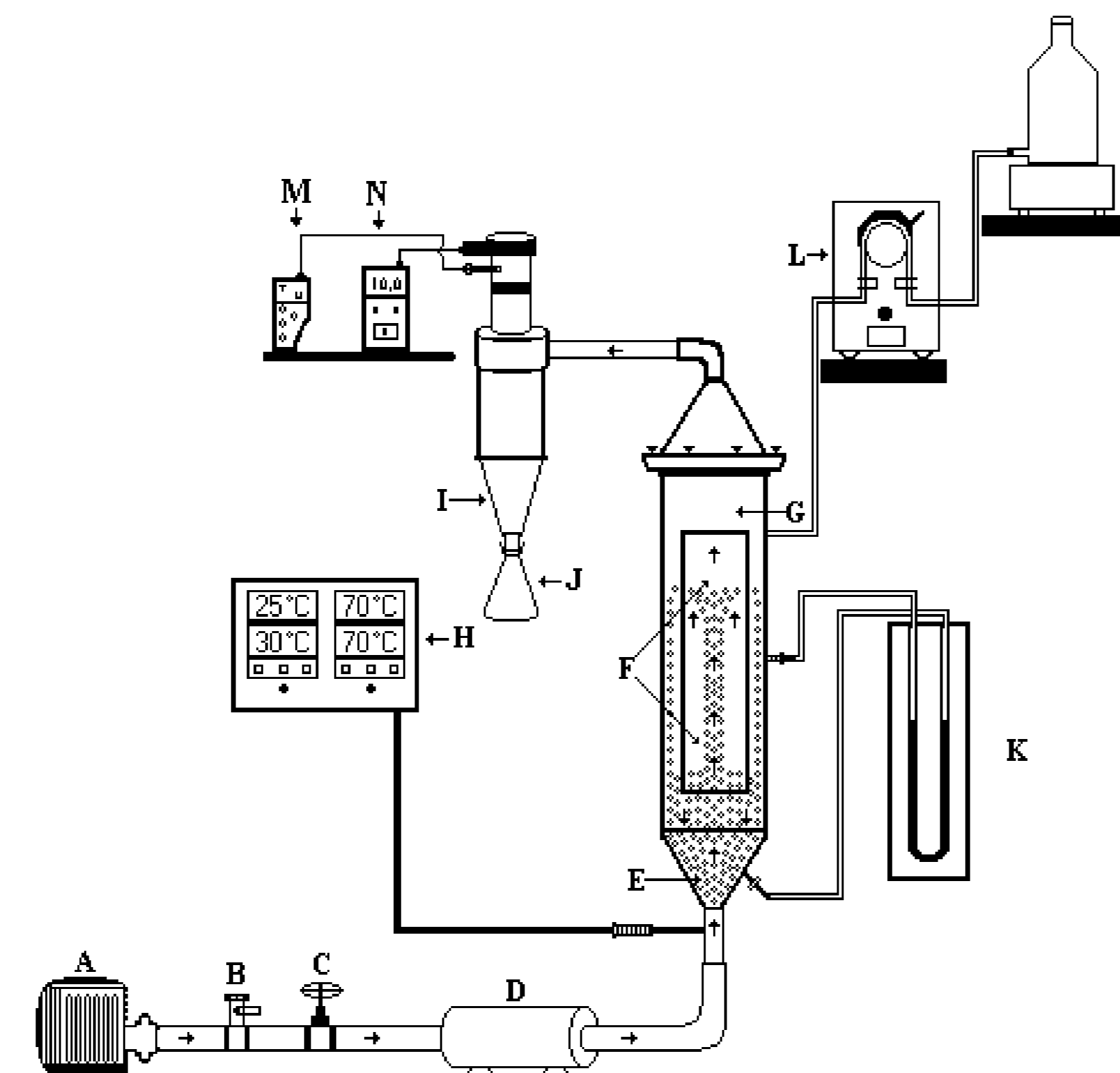


Fig. 1. Schematic diagram of the spouted bed system built in the laboratory of UFRN

RESULTS AND DISCUSSION

Table 4 Results from the two-level full factorial

Variables	Experiment	1	2	3	4	5	6	7	8
		1R	2R	3R	4R	5R	6R	7R	8R
Powder moisture content	W_{pd} (% w.b.)	3.42	2.75	2.59	3.66	3.01	2.33	1.84	2.70
		2.03	3.32	2.12	2.43	3.22	3.25	1.87	3.63
Powder production efficiency	EF (%)	19.95	32.15	41.65	64.48	3.53	44.30	21.81	54.31
		22.05	27.26	32.96	49.41	2.38	26.56	19.07	47.35
Powder retention on particle surface	Ret (%)	33.16	17.86	32.92	16.99	26.32	28.33	30.91	22.51
		32.48	18.79	32.11	22.45	34.86	24.78	36.55	22.29
Powder adherence to equipment walls	P_{lost} (%)	46.89	49.99	25.43	18.53	70.15	27.37	47.28	23.18
		45.47	53.95	34.93	28.14	62.76	48.66	44.38	30.36

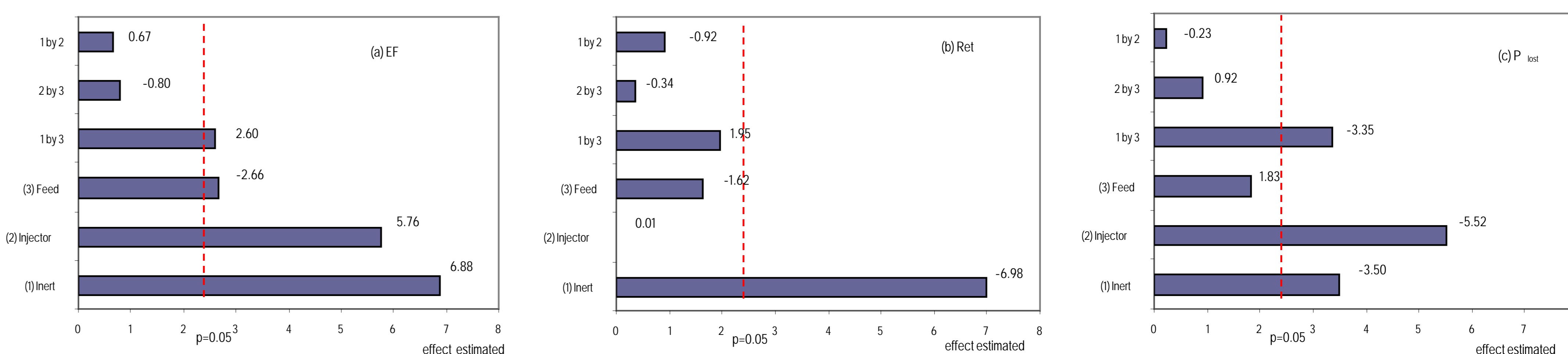


Fig. 2 Pareto Chart of Standardized Effects for the response variables: (a) EF, (b) Ret and (c) P_{lost} .

Table 3 Methods used for measuring milk properties

Powder properties	Methods and procedures
W - moisture content (expressed in wet basis)	<ul style="list-style-type: none"> mass lost after drying 5 to 10 g of powder in an oven at controlled temperature (90$^{\circ}C$) until reaching mass constant
a_w - water activity	<ul style="list-style-type: none"> determining by AquaLab (model 4TE)
Particle size distribution curve:	<ul style="list-style-type: none"> cumulative volume percentage undersize distribution curve of random samples, using CILAS laser particle size analyzer (model 1180); D_p - based on the integration of this distribution curve.
D_p - mean volumetric particle diameter	
ρ_{ap} - apparent powder density	<ul style="list-style-type: none"> volume of 20 g of powder poured gently into a graduated cylinder without tapping
ρ_{ap-max} - tapped apparent powder density	<ul style="list-style-type: none"> volume of 20 g of powder poured in a closed graduated cylinder and tapped (drop it from a horizontal surface of 20 cm height, 40 times)
HR - Hausner cohesion number	$HR = \frac{\rho_{ap-max}}{\rho_{ap}} \quad (1)$
θ - angle of repose	<ul style="list-style-type: none"> internal angle between the powder pile and the horizontal surfaces, after allowing powder to flow freely through a funnel onto the horizontal surface forming an stable pile
Sol - solubility (in water)	<ul style="list-style-type: none"> mass of soluble solids per g of powder (after 5 min of magnetic agitation and 5 min of centrifugation at 2600 rpm)
W_{eq} vs. a_w - Sorption curve at 25 $^{\circ}C$	<ul style="list-style-type: none"> consecutive measurements of water activity and its equilibrium moisture content of powder samples, initially storage under 92 % of air relative humidity, using AquaLab (model 4TE).
Emulsion properties	Methods and procedures
σ - surface tension	<ul style="list-style-type: none"> measured by a tensiometer (CSC-Du NOY) using the ring method
μ - apparent viscosity	<ul style="list-style-type: none"> measured by a rheometer (RheoStress Haake, model RS-150)
c_p - specific heat	<ul style="list-style-type: none"> measured by a calibrated thermal analyzer (KD2 Decagon)
k - thermal conductivity	
ρ_{milk} - milk emulsion density	<ul style="list-style-type: none"> measured by standard 50 ml pycnometers previously calibrated.

Table 5 Goat milk properties for analyzed samples

Powder properties	SD powder (1 month)	SB powder (1 month)	SB powder (6 months)
W (% w.b.)	4.94 (± 0.09)	3.44 (± 0.10)	5.84 (± 0.17)
a_w (-)	0.30 (± 0.04)	0.27 (± 0.01)	0.57 (± 0.03)
D_p (μm)	265	219	221
ρ_{ap} (kg/m^3)	421 (± 14)	357 (± 12)	358 (± 16)
ρ_{ap-max} (kg/m^3)	667 (± 14)	556 (\pm)	538 (± 20)
HR (-)	1.62 (± 0.06)	1.56 (± 0.05)	1.51 (± 0.09)
θ ($^{\circ}$)	55 (± 1)	49 (± 6)	47 (± 4)
Sol (-)	1.00 (± 0.01)	0.89 (± 0.10)	0.76 (± 0.02)
Sorption curve - adjust to Gab model:			
	$W_{eq} = \frac{c_1 c_2 c_3 a_w}{(1 - c_1 a_w)(1 + (c_3 - 1)c_2 a_w)} \quad (2)$		
c_1 ; c_2 and c_3	1.481; 0.989; 0.099	0.073; 0.882; 31.9	-
Emulsion properties	Raw goat milk	SD reconstituted milk	SB reconstituted milk
W (% w.b.)	87.0	88.2	88.0
σ (mN/m)	36.2 (± 0.2)	37.5 (± 0.2)	39.3 (± 0.1)
μ (Pa s)	0.002	0.003	0.003
c_p (kJ/kg K)	4.8 (± 0.1)	4.3 (± 0.4)	4.6 (± 0.7)
k (W/m K)	0.56 (± 0.01)	0.46 (± 0.05)	0.56 (± 0.05)
ρ_{milk} (kg/m^3)	1032	1035	1038
a_w (-)	0.987 (± 0.003)	0.991 (± 0.002)	0.988 (± 0.002)

CONCLUSIONS

- Spout-bed unit must operate under the following conditions to minimize P_{lost} (adherence to equipment walls) and Ret (retention on inert particle surface), and to maximize EF (powder production efficiency): inert material - polypropylene particles, the milk emulsion feed mode - intermittent, and the type of injector - the drop-injector.
- Properties of goat milk powder produced in the SB unit under these more adequate conditions are well compared to those of industrial SD (spray-dryer) goat milk powder (Table 5). These results validate the high quality of the SB powder produced. Moreover, it presents lower W, smaller agglomerates (decrease in D_p), and a tendency to be lesser cohesive (very small decrease in HR and θ). These characteristics favor its use as an intermediate product in the local food industries and agro-cooperatives.
- Results corroborate the feasibility of producing goat milk powder in a low-cost spouted-bed dryer with high quality.

