THE IMPORTANCE OF FLUIDIZATION PARAMETERS FOR THE PRODUCTION OF QUALITY BLACK TEA AT HIGHER EFFICIENCIES

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Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Dedication

I would like to recollect the love and earnest encouragement from my wife without whose loving care and inspiration it would not have been possible for me to come up this far in life.

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Abstract

Orthodox broken type teas, currently producing in tea factories in Sri Lanka, have on average smaller size particles than that of tea produced a decade ago. However most of the tea factories still use the conventional fluid bed dryers and hence they are experiencing difficulties in achieving fluidization with required co-existence of continuous phase and bubble phase. In the present study, fluidization behavior of Orthodox broken type tea was examined in a pilot-scale fluid bed dryer. Six different bedplate configurations were evaluated against the conventional bedplate having perforations of 36 mm × 0.5 mm with 3.4 % opening area. The bedplate of 36 mm × 0.6 mm with 5 % opening area gave the best performance. A stable fluidized tea-bed with co-existence of continuous phase and bubble phase was achieved without stagnation and entrainment at higher loadings of 44.5 – 50.5 kg/m^2 than the conventional loading of 38.5 kg/m^2. Further, the fluctuations were found to be minimized for a wide range of fluidizing velocities of 1.3 - 1.9 m/s.

A new mathematical model was developed to predict the minimum fluidization velocity by correlating dimensionless Archimedes number, Reynolds number and moisture ratio. The variations in particle size and particle density due to shrinkage during the drying process were incorporated in the new model. The predicted fluidization velocity was found to be in good agreement with the experimental data and the difference was below 10 % for majority of the cases. An empirical model relating the dimensionless moisture ratio to an easily measurable parameter, tea-bed temperature, was also proposed and validated.

Drying characteristics of Orthodox broken type tea and the quality variations with the fluidization parameters were also examined using a laboratory-scale fluid bed dryer. Page model was found to give better predictions than the other thin-layer drying models. Free moisture was found to be present above moisture contents of 60 % (w/w, dry basis) and the effective diffusivity was found to be 2.52 x 10^{-11} m^2/s. During the final stage of drying, effective diffusivity was found to vary between 2.660 x 10^{-11} m^2/s and 2.782 x 10^{-11} m^2/s. Quality variations were examined by the method of chemical analysis and organoleptic analysis. The results indicated that better quality tea could be achieved with higher loadings than conventional loading of 38.5 kg/m^2 and lower hot air temperatures than the conventional temperature of 124 °C. However, the drying time was found to increase by 22-33 % for higher loadings and by 12 – 77 % for lower hot air temperatures.

Keywords: Orthodox broken type tea, minimum fluidization velocity, shrinkage, moisture ratio, thin-layer drying model

TABLE OF CONTENTS **Page**

LIST OF FIGURES **Page**

LIST OF TABLES **Page**

LIST OF ABBREVIATIONS

Abbreviation	Description
BOPF	Broken Orange Pekoe Fannings
BP	Bedplate
BR	Brightness
CBSL	Central Bank of Sri Lanka
CTC	Crush Tear Curl
ECM	Environmentally Controlled manufacture
FBD	Fluid Bed Dryer
PID	Proportional–Integral–Derivative
PWM	Pulse-Width Modulation
RH	Relative Humidity
RMSE	Root Mean Square Error
TC	Total Colour
TF	Theaflavin
TR	Thearubigin
VSD	Variable Speed Drive

LIST OF NOMENCLATURE

Symbols	Description
Ar	Archimedes Number
d_i	mean diameter of the size interval of sieves (μm)
d_p	mean particle size (μm)
g	gravitational acceleration constant (m/s^2)
$ERe_{mf}(\%)$	Percentage absolute error for Reynolds number at minimum fluidization
Re_{mf}	Reynolds number at minimum fluidization
$Re_{mf}(calc)$	Calculated value of Reynolds number at minimum fluidization
$Re_{mf}(exp)$	Experimental value for Reynolds number at minimum fluidization
u_{mf}	minimum fluidization velocity (cm/s)
W	average moisture content in percentage (w/w, dry basis)
W_e	equilibrium moisture content in percentage (w/w, dry basis)
W_i	initial moisture content in percentage (w/w, dry basis)
X_i	weight fraction in the size interval of sieves
ρ_g	density of fluidizing air (kg/m^3)
ρ_p	Particle density of dhool (kg/m^3)
μ	dynamic viscosity of fluidizing air (kg/m/s)
ϕ	dimensionless moisture content
t	drying time
M	Average moisture content
M_o	initial moisture content
M_e	equilibrium moisture content
A_o, k_o, A_1, k_1, n	empirical coefficients
χ^2	Chi-square
D_{eff}	Effective diffusivity
T	Tea-bed temperature
ΔP	Total differential pressure

LIST OF APPENDICES