Applied Mathematics for Malting and Brewing Technologists

Technological Calculations, Benchmarks and Correlations for Process Optimization

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Contents

Abbreviations and symbols

Note: In all calculations the metric system is used. For the conversion of SI units into other measument systems see Chapter 19.

abv	alcohol by volume
A	area, surface
A_C	alcohol content in % m/m or % v/v
A_S	area of a sphere
B	barley
B.a.GM	barley as green malt
b	width
BFM	bottle filling machine
BCM	bottle cleaning machine
BU	EBC bitterness unit
c, c_P	specific heat capacity
CCV	cylindroconical tank
cps	cycles per seconds
c_Y	yeast concentration
d	day
d, Ø	diameter
DE	diatomaceous earth
DFS	dosing filter system
DM	dry matter, dry mass
DM_B	barley dry matter
DM_M	malt dry matter
DM_Y	yeast dry matter
DM_{YI}	yeast dry matter increase
DMS	dimethylsulfide
e	constant e = 2.71828
E	energy
E	element
E	evaporation
E_C	extract content
E_1	existing apparent residual extract in percent
E_2	already fermented apparent extract in percent
E_3	spindled value of the final fermentation sample in percent
E_4	still available fermentable residual extract in percent ($E_1 - E_3$)
E_5	$0.81 \cdot E_2$
E_{PW}	extract of the pitching wort at 20 °C
E_R	evaporation rate
FA	filter aid
FAN	free amino acids
F°	degree of fermentation
$F°_{ap}$	degree of fermentation apparent
$F°_{apf}$	degree of fermentation apparent final
$F°_{aplc}$	degree of fermentation in the lager cellar
$F°_{real}$	degree of fermentation real
FB	finished beer
FD	finished drink
FM	finished malt
FW	finished wort
g	acceleration of gravity = 9.81 m/s^2
GM	green malt
h	height
h	hour
h	enthalpy
HE	heat exchange
hL	hectoliter
k	heat transfer coefficient
K	temperature in Kelvin
l	length
L	liter
m	mass
$\dot{m}$	mass flow rate
M	malt
M_C	moisture Content
MEV	malt equivalent value
M_{GL}	grist load
mL	milliliter
NTP	normal temperature and pressure

OG	original gravity
OG_{PW}	original gravity of the pitching wort
OG_{CKW}	original gravity of the cold knockout wort
OG_{HKW}	original gravity of the hot knockout wort
OG_{FB}	original gravity of the finished beer
OP	overpressure
p	pressure
P	power
Pe	perimeter
PHE	plate heat exchanger
PU	pasteur Units
PW	pitching wort
Q	heat quantity
Q_{set}	set filling amount
$\dot{Q}$	heat flow rate
q	specific heat quantity
r	radius
r	heat of evaporation
RE_{FB}	real extract of the finished beer at 20 °C
rpm	rotations per minute
s	seconds
s	speed
S°	steeping degree
spec.	specific
SG	spent grain
STHE	shell and tube heat exchanger
STHS	short time heating system / flash pasteurizer
SS	sugar sirup

t	time
t_B	average boiling time
TCC	trough chain conveyor
UMB	un-malted barley
V	volume
$\dot{V}$	volume flow
V_{CKW}	volume of cold knockout wort
V_{FW}	volume of first wort
V_{HKW}	volume of hot knockout wort
VKFW	volume of kettle full wort
V_{Ma}	volume of mash
V_{PW}	volume of pitching wort
V_{SG}	volume of spent grain
W	specific main striking volume
W	water
W_C	Water content
WC	water column
W_D	delivery work
x	humidity
y	year
Y	yield
Y_{ffm}	yield of fine flour malt in the air-dried state
Y_{BH}	brewhouse yield
Y_{Bit}	bitterness utilization in percent
Y_{eff}	brewhouse efficiency
Y_{OBY}	overall brewhouse yield
% m/m	% mass/mass
% v/v	% volume/volume

α	angle
α	heat transfer coefficient
Δ	difference
$\Delta\vartheta$	temperature difference
η	dynamic viscosity
ϑ	temperature in degrees Celsius
λ	gas solubility
λ	thermal conductivity

μ	micro
ν	kinematic viscosity
π	pi = 3.1416
ρ	density
σ	mechanical tension
σ	population standard deviation
φ	relative humidity
ω	angular velocity

Statistics

$\Delta \bar{x}$	confidence interval	s^2	variance
$\bar{x}$	mean	P	statistical certainty
σ^2	population variance	t	test statistic
Q	test value	CV	coefficient of variation
r^2	coefficient of determination (= B)	a_0	regression constant
s	standard deviation		

Indices e.g.

A	air	GR	grist
A	actual	HKW	hot knockout wort
a	average	I	increase
ad	air dried	KF	kettle full wort
ap	apparent	L	laboratory
B	barley	L	losses
B	buffer	M	malt
BH	brewhouse	Ma	mash
Bit	bitterness	MF	main fermentation
bbl	barrel	P	pyramid
C	cylinder	PM	pilsner malt
C	content	PW	pitching wort
cal	calculate	R	rate
CA	caramel	req	required
CKW	cold knockout wort	real	real
CM	content malt	S	sphere
Co	cone	SD	spherical dome
CS	conical section	SG	spent grain
CU	cuboid	SM	sour malt
eff	effective	SV	strike volume / water
Ex	extract	SpV	sparging volume
eth	ethanol	t	total
f	final	TE	total evaporation
F	frustum	Tc	truncated cone or frustum
F	factor	V	vapor
FB	finished beer	W	water
FW	first wort	Y	yeast
G	grain		

High abv beer	≥16 °Plato OG
Low abv beer	<11 °Plato OG
Full beer	≥11 and <16 °Plato OG
Pilsner type beer	≈ 12 °Plato OG

Overview of calculation examples

Preface

The most well known texts on applied mathematics for maltsters and brewers [1], [2], [3] are over 50 years old and no longer meet the requirements of the 21st century. A modernized textbook for brewers and maltsters revised by *R. Simon* [4] was released in 1986 and thus is thirty years old. Furthermore in 2003 the Master Brewers Association of Americas released an interesting handbook for basic brewing calculations [5], but it utilizes only Anglo-American measurement units.

The purpose of this reference book is to provide an overview of technological calculations and guidelines from literature, which are supplemented by self-determined correlations and statistically reliable relationships. These are helpful for trainees, practitioners, and students to optimize process management in beer production.

Furthermore, tables and graphs needed for technological calculations are included in a manner to enable rapid solutions without long searches.

The information required for assessing the results including reference values found in literature are presented without much explanation of the technological, biochemical, microbiological, and technical relationships. For understanding the requisite technology studies referenced modern literature see [6], [7], [8], [9], [10], [11], [12], [13], [14], [15].

In addition to the computational approaches, there are sample calculations with solutions to assist students and skilled workers gain a deeper understanding of the subject matter. From these computational approaches and sample calculations, easy operation-specific tasks can be derived.

Especially for small breweries that do not have large analytical study capacity, simpler technological approximate solutions are proposed.

Finding the solution of these tasks require basic knowledge of the handling of a calculator with integrated trigonometric, logarithmic, and simple statistical functions.

The use of the included equations for creating universally usable calculation documents with the help of Excel® is strongly recommended.

Power supply for the brewing and malting industry (heat, cold, and electricity), compressed air supply, and CO_2 recovery are not dealt with in this textbook, because of the extent of information already available in literature, for example, [16], [17], [18] and [19].

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