YEAST METABOLISM IN FRESH AND FROZEN DOUGH

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ABSTRACT

Fresh bakery products have a very short shelf life, which limits the extent to which manufacturing can be centralised. Frozen doughs are relatively stable and can be manufactured in large volumes, distributed and baked on-demand at the point of sale or consumption. With appropriate formulation and processing a shelf life of several months can be achieved.

Shelf life is limited by a decline in proofing rate after thawing, which is attributed to a) the dough losing its ability to retain gas and b) insufficient gas production, i.e. yeast activity. The loss of shelf life is accelerated by delays between mixing and freezing, which allow yeast cells the chance to ferment carbohydrates.

This work examined the reasons for insufficient gas production after thawing frozen dough and the effect of pre-freezing fermentation on shelf life. Literature data on yeast metabolite dynamics in fermenting dough were incomplete. In particular there were few data on the accumulation of ethanol, a major fermentation end product which can be injurious to yeast.

Doughs were prepared in a domestic breadmaker using compressed yeast from a local manufacturer and analysed for glucose, fructose, sucrose, maltose and ethanol. Gas production after thawing declined within 48 hours of frozen storage. This was accelerated by 30 or 90 minutes of fermentation at 30˚C prior to freezing.

Sucrose was rapidly hydrolysed and yeast consumed glucose in preference to fructose. Maltose was not consumed while other sugars remained. Ethanol, accumulated from consumption of glucose and fructose, was produced in approximately equal amounts to CO_2, indicating that yeast cells metabolised reductively.

Glucose uptake in fermenting dough followed simple hyperbolic kinetics and fructose uptake was competitively inhibited by glucose. Mathematical modelling indicated that diffusion of sugars and ethanol in dough occurred quickly enough to eliminate solute gradients brought about by yeast metabolism.

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DETA	dielectric thermal analysis	
DM	dry matter	
DMA	dynamic mechanical analysis	
DMTA	dynamic mechanical thermal analysis	
DSC	differential scanning calorimetry	
DTA	differential thermal analysis	
NMR	nuclear magnetic resonance	
SD	standard deviation	
SE	standard error	
TAM	total available monosaccharides	[mmol.(100g dough)$^{-1}$]

LIST OF SYMBOLS USED

a_w	water activity	-
A	area	[m^2]
A_{dough}	area of dough per yeast cell	[mm^2]
c	solute concentration	[mol.L^{-1}]
D	diffusion coefficient	[m^2.s^{-1}]
D_e	estimated diffusion coefficient for ethanol diffusing in dough aqueous phase	[cm^2.s^{-1}]
D_g	estimated diffusion coefficient for glucose diffusing in dough aqueous phase	[cm^2.s^{-1}]
E	ethanol concentration	[mol.L^{-1}]

E_i	initial ethanol concentration	[mol.L^{-1}]
E_{max}	maximum ethanol concentration at which sugar uptake occurs	[mol.L^{-1}]
F_i	initial fructose concentration	[mol.L^{-1}]
G_i	initial glucose concentration	[mol.L^{-1}]
G_R	glucose consumption rate (microsystem model)	[mol.L^{-1}.min^{-1}]
i	space partition point number	-
j	time partition point number	-
J	diffusion flux	[mol.m^{-2}.s^{-1}]
$J(x)$	diffusion flux at position x	[mol.m^{-2}.s^{-1}]
k	Boltzmann constant	[N.m.K^{-1}]
K_i	competitive inhibition constant	[mol.L^{-1}]
K_m	affinity constant	[mmol.L^{-1}]
L	radius of the sphere of aqueous phase in the microsystem model	[m]
M	molar mass	[g.mol^{-1}]
n	number of samples or replicates	-
Q_{st}	net isoteric heat of adsorption	[kJ.mol^{-1}]
r	surface radius of curvature	[m]
r_{dough}	radius of the hypothetical circle of dough allocated to each yeast cell	[mm]
R	universal gas constant	[N.m.K^{-1}.mol^{-1}]
S	sugar concentration	[mmol.L^{-1}]
S_A	concentration of substrate A	[mmol.L^{-1}]
S_I	concentration of inhibitor	[mmol.L^{-1}]
t	time	[min]

t_n	time co-ordinate number ‘n’	-
ΔT_f	freezing point depression	[˚C]
T	absolute temperature	[K]
V	rate of sugar uptake	[mmol.L^{-1}.h^{-1}]
V_m	mean volume	[ml]
V_M	molar volume	[m^3.mol^{-1}]
V_{max}	maximum specific rate of sugar uptake	[mmol.(g biomass)$^{-1}$.h^{-1}]
V_G	glucose uptake rate	[mmol.(100g dough)$^{-1}$.min^{-1}]
V_F	fructose uptake rate	[mmol.(100g dough)$^{-1}$.min^{-1}]
x_n	space co-ordinate number ‘n’	-
X	biomass concentration	[g.L^{-1}]
Y_{ef}	molar yield of ethanol from fructose	-
Y_{eg}	molar yield of ethanol from glucose	-

GREEK SYMBOLS

α	ethanol inhibition coefficient	-
γ	surface tension	[N.m^{-1}]
η	coefficient of viscosity	[N.s.m^{-2}]
π	3.14159	-
ρ	density	[g.m^{-3}]