LAMPIRAN A
DATA-DATA

Tabel 1. Hasil Pengamatan Massa Bahan, Temperatur Bola Basah, dan Temperatur Bola Kering Pada Suhu Udara Pengering 60^{o}C.

Waktu (Menit)	Berat (Gram)		Temperatur Udara Pengering (°C)	Temperatur (°C)	
	Awal	Akhir		bb	bk
30	1000	660.73	60	29	50
90	660.30	400.43	60	31	50.5
150	400.43	350	60	31	53
210	350	300.25	60	29	54
270	300.25	300	60	31	58

Tabel 2. Data Pengamatan Laju Udara, *Humidity* dan Temperatur Bahan pada Suhu Udara Pengering Pengeringan (60^{o}C).

Waktu (Menit)	Temperatur Udara Pengering (^{o}C)	Laju udara Masuk (m/s)	Laju Udara Keluar (m/s)	*Humidity* (kgH_2O/kg) udara Kering	Temperatur Udara Keluar (^{o}C)
30	60	25.22	25.26	0.013	30
90	60	25.25	25.27	0.014	42
150	60	25.21	25.29	0.016	44
210	60	25.27	25.39	0.018	46
270	60	28.92	30.90	0.019	46

Tabel 3. Data pengamatan Kadar Air (%) Ubi Kayu pada Suhu udara Pngeringan 60^{o}C.

Waktu (Menit)	Masa Cawan Petri + Bahan Sebelum dioven (gram)	Masa Cawan Petri + Bahan Sesudah dioven (gram)	Berat Bahan (gram)		Kadar Air (%)
			Sebelum dioven	Sesudah dioven	
30	25.6	26.4	2	0,8	60
90	25.6	26.7	2	1,1	46.5
150	25.6	26.9	2	1.3	35
210	25.6	28.2	2	1.7	12.5
270	25.6	27.7	2	1.9	1.95

LAMPIRAN B
PERHITUNGAN

1. Perhitungan Desain *Rotary Dryer*

Dalam merancang alat pengering tipe *rotary dryer*, terdapat tahap – tahap yang perlu dilakukan, diantaranya :

- Kehilangan panas dari permukaan *rotary dryer* diabaikan
- Kapasitas dari *dryer* diketahui dan juga berdasarkan dengan neraca massa dan panas.

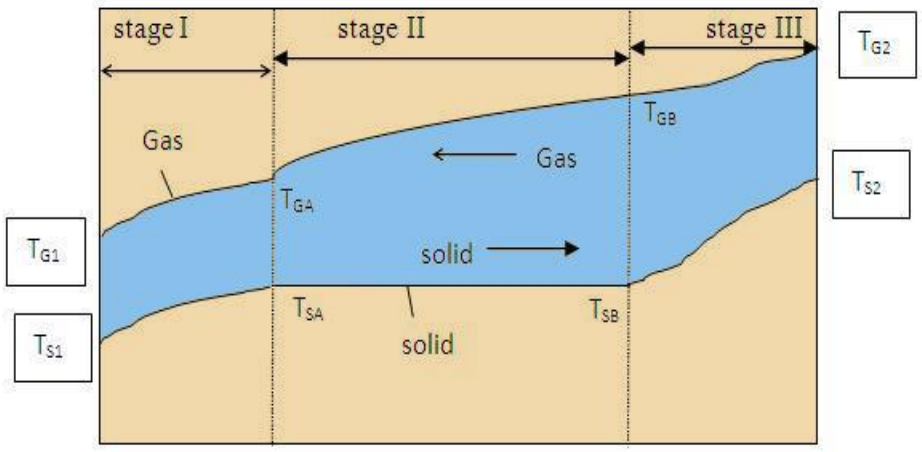
  $Gs\ (Y_1 - Y_2) = Ms\ (X_1 - X_2)$

  $Gs\ (H_{g2} - H_{g1}) = Ms\ (H_{s2} - H_{s1})$

  Dimana, Gs = laju alir udara (udara kering, kg/jam), Ms = Laju alir padatan (kg/jam)
- Ntu (*Number of Transfer Unit*) untuk setiap zona dihitung, untuk stage II nilai Ntu :

  $(N_{tG})_{,II} \times \Delta Tm = (T_{GB} - T_{GA})$
- Menghitung total panjang dari *dryer* :

  $L = (L_T)_1\ (N_{tG})_1 + (L_T)_{II}\ (N_{tG})_{II} + (L_T)_{III}\ (N_{tG})_{III}$
- Diameter dari *dryer* dihitung dari laju alir udara dan kecepatan udara yang masuk.



Feed : 5 kg ubi kayu/jam

Kandungan air : 62 % (awal)

Kandungan air : 12% (akhir)

Cp ubi kayu : 1652,2 + $\frac{5835.X_B}{1+X_B}$ (Pérez-Alegría *et al*., 2001)

Temperatur awal padatan (T_{S1}) : 30 ^{O}C

Temperatur udara masuk (T_{G2}) : 80 ^{O}C

Temperatur akhir padatan (T_{S2}) : 50 ^{o}C

Temperatur udara keluar (T_{G1}) : 40 ^{o}C

Basis : 1 jam operasi

Mass of dry solid (M_S) : 5 (1 – 0,62) = 1,9 kg

Kandungan air pada wet solid (X_1) = 62/(100 -62) = 1,6315 kg

Kandungan air di dry solid (X_2) = 12/(100 – 12) = 0,1364 kg

Air yang teruapkan = M_S ($X_1 – X_2$) = 1,9 (1,6315 – 0,1364) = 2,8407 kg

Asumsi suhu gas keluar (T_{G2}) = 40^{o}C

- **Menghitung entalpi (padatan)**

Cp Ubi Kayu (62%) = 5.591T + 1239 (Gevaudean dkk, 2008 hlm 466)

= 5.591 (30^{o}C) + 1239

= 1406,73 j/kg^{o}C = 1,407 kJ/kg K

H_{S1} = [$Cp_{ubi\ kayui}$ + Cp_{air} .X_1] ($T_{S1} – T_{ref}$) (Geankoplis,1993)

= [1,407 kJ/kg K + (4,187)(1,6315)] (303 – 273)

= 246,849 kJ/kg dry solid

Cp Ubi Kayu (12%) : 5.591 T + 1239

= 5.591 (50^{o}C) + 1239

= 1518,55 J/kg.K = 1,5186 kJ/kg.K

H_{S2} = [$Cp_{ubi\ kayu}$ + Cp_{air} .X_2] ($T_{S2} – T_{ref}$)

= [1,5186 + (4,187)(0,1364)] (323 – 273)

= 104,4581 kJ/kg dry solid

- **Menghitung entalpi untuk gas**

$H_{G2} = [\ 1{,}005 + (1{,}88)Y_2]\ (T_{G2} - 0) + \lambda_0\ Y_2$

$= [\ 1{,}005 + (1{,}88)(0{,}0185)]\ (70 - 0) + 2501(0{,}0185)$

$= 119{,}0531$ kJ/kg *dry air*

$H_{G1} = [\ 1{,}005 + (1{,}88)Y_1]\ (T_{G1} - 0) + \ 2501\ Y_1$

$= [\ 1{,}005 + (1{,}008)Y_1]\ (40 - 0) + \ 2501\ Y_1$

$= 40{,}2 + 75{,}2Y_1 + \ 2501\ Y_1$

$= 40{,}2 + 2576{,}2\ Y_1$ ..... (1)

Neraca Massa secara Keseluruhan

$G_S\ (Y_1 - Y_2) = M_S\ (X_2 - X_1)$

$G_S\ = \frac{2{,}8407}{(Y_1 - 0{,}0185)}$ . ..... (2)

Neraca Panas

$M_S\ (H_{S2} - H_{S1}) = G_S\ (H_{G2} - H_{G1})$

$1{,}9(104{,}4581 - 246{,}849) = (\frac{2{,}8407}{(Y_1 - 0{,}0185)})[119{,}0531 - (40{,}2 + 2576{,}2\ Y_1\ \ \ \ )]$

$-270{,}5427 = (\frac{2{,}8407}{(Y_1 - 0{,}0185)})[119{,}0531 - 40{,}2 - 2576{,}2\ Y_1]$

$-270{,}5427 = (\frac{223{,}998 - 7318{,}2113 Y_1}{(Y_1 - 0{,}0185)})$

$-270{,}547\ Y_1 + 5{,}005 = 223{,}998 - 7318{,}2113\ Y_1$

$(-270{,}5427\ Y_1 + 7318{,}2113)\ Y_1 = 223{,}998 - 5{,}005$

$7047{,}6686\ Y_1 = 218{,}993$

$Y_1 = 0{,}0311$

- **Menghitung volum humid keluar (v_{outlet}), T_{G1} = 40°C**

$V_H = \frac{22{,}41}{T}(\frac{1}{28{,}79} + \frac{1}{18{,}02} Y_1)$

$= \frac{22{,}41}{313}(\frac{1}{28{,}79} + \frac{1}{18{,}02}\ 0{,}0311)$

$= 0{,}0026\ m^3$/kg udara kering

- **Menghitung nilai Laju alir Gas Volumetrik**

$G_S\ = \frac{2{,}8407}{(Y_1 - 0{,}0185)}$ (substitusi nilai Y_1 ke persamaan 2)

$G_S = \frac{2,8407}{(0,0311-0,0185)} = 225,4524$ kg/jam

Max. vol gas = G_S x V_{H2}

= 225,4524 (0,0026) = 0,5862 m^3/jam

- **Menghitung Diameter *Rotary Dryer***

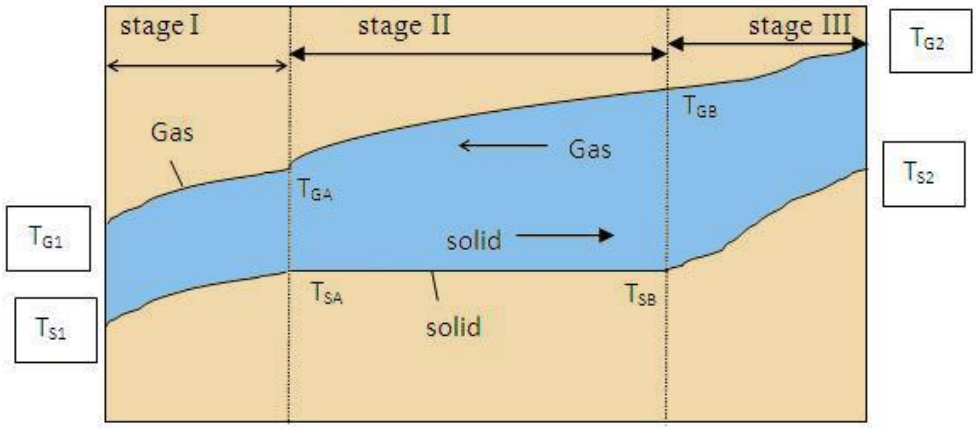
Kecepatan udara masuk : 2,5 m/jam

$A = \frac{0,5862}{2,5} = 0,2345\ m^2$

$D = (\frac{4.A}{\pi})^{0,5} = (\frac{4\ (0,2345)}{3,14})^{0,5} = 0,5466\ m$

- **Menghitung nilai Heat Transfer Unit (Ntu)**

Dalam proses pengeringan terjadi 3 zona pengeringan yaitu, pemanasan, penguapan, dan pengeringan. Sehingga dapat digambarkan grafik dibawah ini:



- **Menghitung nilai N_{tU} di Stage III**

Dengan mengasumsi $T_{SA} = T_{SB} = 40\ ^oC = 313$ K

H_{SB} = $[Cp_{ubi\ kayui} + Cp_{air} .X_2] (T_{S2} – T_{ref})$

= [1,407 + (4,187)(0,1364)] (313 – 273)

= 79,0915 kJ/kg dry solid

C_{HB} = 1,005 + 1,88 (Y_2)

= 1,005 + 1,88 (0,0185)

= 1,0398

$M_S\,(H_{S1} - H_{SB}) = G_S\,.C_{HB}.(T_{G2} - T_{GB})$ (Geankolis,1993)

1,9 (104,4581 – 79,0915) = 225,4524 (1,0398) (80 – T_{GB})

T_{GB} = 79,7944^{o}C

$\Delta T_B = 80 - 50 = 30$

$\Delta T_a = 79{,}7944 - 40 = 39{,}7944$

$$\Delta tm = \frac{39{,}7944 - 30}{ln\frac{39{,}7944}{30}} = 34{,}6704$$

$$N_{tG(III)} = \frac{T_{G2} - T_{GB}}{\Delta tm} = \frac{80 - 79{,}7944}{34{,}6704} = 0{,}0059$$

- **Menghitung nilai N_{tU} di Stage II**

T_{SB} = 40 ^{o}C, T_{GB} = 79,7944 ^{o}C

$H_{SA} = [Cp_{ubi\ kayu} + Cp_{air}\,.X_2]\,(T_{S2} - T_{ref})$

= [1,407 + (4,181)(1,6315)] (313 – 273)

= 329,1321 kJ/kg dry solid

$H_{GB} = [1{,}005 + 1{,}88(Y)][T_{GB} - T_{ref}] + 2501.Y$

= 1,005 + 1,88 (0,0185)[79,7944 – 0] +2501 (0,0185)

= 129,237 kJ/kg udara kering

Neraca Panas di Stage II

$M_S\,(H_{SA} - H_{SB}) = G_S.(H_{GB} - H_{GA})$

1,9 (329,1321 – 79,0915) = 225,4524 (129,237 – H_{GA})

H_{GA} = 127,1298 kJ/kg udara kering

$H_{GA} = [1{,}005 + 1{,}88(Y)][T_{GA} - T_{ref}] + 2501.Y$

127,1298 = [1,005 + 1,88 (0,0311)] [T_{GA}] + 2501 (0,0311)

T_{GA} = 54,703 ^{o}C

$\Delta T_B = 6{,}4134 - 40 = 6{,}4314$

$\Delta T_a = 79{,}7944 - 40 = 39{,}7944$

$$\Delta tm = \frac{39{,}7944 - 6{,}4314}{ln\frac{39{,}7944}{6{,}4314}} = 18{,}3061$$

$$N_{tG(II)} = \frac{T_{Gb} - T_{GA}}{\Delta tm} = \frac{79{,}7944 - 46{,}4314}{18{,}3061} = 1{,}82$$

- **Menghitung nilai N_{tU} di Stage I**

$\Delta T_B = 46{,}4314 - 40 = 6{,}4314$

$\Delta T_a = 40 - 30 = 10$

$$\Delta tm = \frac{6{,}4314 - 10}{ln\frac{46{,}4314}{10}} = 8{,}0847$$

$$N_{tG(I)} = \frac{T_{GA} - T_{G1}}{\Delta tm} = \frac{46{,}4314 - 40}{8{,}0847} = 0{,}7935$$

$N_{Tu} = N_{tG(III)} + N_{tG(II)} + N_{tG(I)}$

= 0,0059 + 1,82 +0,7935 = 2,62

Length Transfer Unit

Laju alir rata – rata udara = $225{,}4524\frac{225{,}4524\ (0{,}0185+0{,}0311}{2} = 231{,}0436$ kg dry air/jam

G' = $\frac{(\frac{231{,}0436}{3600})}{\pi.4.(0{,}5466)^2} = 0{,}0171\ kg/s.m^2$ (Treybal,1981)

Volumetric heat , $U_a = \frac{237.G'^{0{,}67}}{D} = 28{,}3914\ W/m^3.K$

$C_{Hrata-rata}$ = 1051,65 kJ/kg.K

$L_{tu} = \frac{G'.Ch}{Ua} = \frac{0{,}0171(105{,}65)}{28{,}3914}$ = 0,6334 m

Panjang dari *Rotary Dryer*

$L = N_{tU}$ x L_{tU}

= 2,62 x 0,6334 = 01,66 m

- **Menghitung waktu tinggal di dalam *Rotary Dryer***

Hold – up mempunyai range 10 – 15 % volume (Perry,R.H, 8ed, 2008)

$V = \pi.r^2.L$

= 3,14 $(0{,}5466/2)^2$ m^2(1,66) m

= 0,3893 m^3

Besarnya hold up adalah,

Hold up = 10 % .V

= 0,10 (0,3893)

= 0,03893 m^3

Diketahui *bulk density* dari Ubi Kayu adalah 1150 kg/m^3 (Susilawati dkk, 2008)

Waktu tinggal = $\frac{hold\ upx\varphi}{feed\ rate}$

= $\frac{0{,}03893\ m3x1150}{5\frac{kg}{jam}x\ 20} = 0{,}4477jam$

- **Menghitung Ketebalan dari *Rotary Dryer***

Ketebalan minimum shell dapat dihitung dengan persamaan berikut (*Brownell and Young, 1959):*

$$ts = \frac{P.ri}{f.E - 0.6.p} + C$$

Dimana :

ts = tebal shell

P = tekanan desain

ri = jari – jari dalam

f = tekanan maksimum yang diizinkan

E = efisiensi pengelasan

C = korosi yang diizinkan

Bahan konstruksi yang digunakan adalah *stainless steel* dengan :

f = 165 Mpa = 23931,2 psi

E = 0,9 (Brownell & Young,1959)

C = 0,075 in

ri = 1/2D = ½ x 0,39 = 0,195 m = 7,67 in

$P_{operasi}$ = 1 atm = 14,696 psi

Untuk faktor keamanan dipilih 20 %, maka : (Brownell & Young,1959)

P_{desain} = 1,2 x 14,696 = 17,635 psi

$$ts = \frac{17,635\ (10,7598)}{(23931,2)(0,9) - 0.6(17,653)} + 0,075$$

= 0,0838 in = 0,00698 ft = 2,1275 mm

- **Menghitung Daya Motor untuk Menggaerakkan *Rotary Dryer***

Daya motor dari *rotary dryer* dapat dihitung dengan persamaan :

BHP = $\frac{(N.4,75.D.w)+(0,1925D'.w)+(0,33W)}{100000}$ (Perry,R.H, 8ed, 2008)

Dimana,

D = Diameter dalam, ft

D' = Diameter *rotary dryer*, ft

W = Total berat Bahan berputar (bahan dan alat), lb

w = berat material yang dikeringkan, lb

sehingga :

Total Hp untuk penggerak *rotary dryer* =0,5 D^2 – D^2

Diambil power = 0,75 D^2

= 0,75 (1,7933 ft)^2 = 2,4119 Hp

Berat *shell*

Volume dari shell = $\frac{\pi.L(D'^2-D^2)}{4}$

= $\frac{3,14(5,4462\ ft)(11,7933^2-1,786)2}{4}$

= 0,01117 ft^3

Berat shell = V_{shell} x $\rho_{stainless\ steel}$

= 0,1117x 480 lb/ft^3

= 53,616 lb.

1. **Menghitung Laju Pengeringan (R_c) pada temperatur 60 °C dan waktu 30 menit.**

$$Vh = 22,4\ x\ \frac{1}{P}\ x\ \frac{T}{273}\ \left(\frac{1}{29} + \frac{1}{18}Y\right)$$ (Geankoplis)

$= 22{,}4\ x\ \frac{1}{1}\ x\ \frac{50+273}{273}\ \left(\frac{1}{29}+\frac{1}{18}\ x\ 0{,}013\right)$

$= 0{,}935022\ m^3/kg$ udara kering

$$\rho_G = \frac{1+H}{V_h}\ (Mc.Cabe\ 1985)$$

$$= \frac{1+0{,}013\ kg}{0{,}935022\ m^3}$$

$= 1{,}0571930\ kg/m^3$

$$G = V\ x\ \rho_G \text{ x } 3600 \text{ (Mc. Cabe 1985)}$$

$= 25{,}22 \text{ x } 1{,}055719 \text{ x } 3600$

$= 98574{,}59\ kg/jam\ m^2$

$$h_y = 0{,}0204\ x\ G^{0{,}8} \text{(Mc. Cabe 1985)}$$

$= 0{,}0204\ x\ (98574{,}59)^{0{,}8}$

$= 201{,}67\ W/m^2\ K$

$$R_c = \frac{h_y(T-T_W)}{\lambda_w}\ (Mc.Cabe\ 1985)$$

$R_c = \frac{201{,}67(50-29)}{2433{,}1} = 1{,}7405\ kg/jam\ m^2$

2. Menghitung Kadar Air Ubi Kayu

a. Kadar Air Awal Ubi Kayu

1. Massa cawan kosong = 48,9 gr
   Massa cawan + sampel basah = 51,77 gr
   Massa cawan + sampel kering = 49,71 gr

Sehingga

$$kadar\ air\ (\%) = \frac{(w1-w2)}{w1-w0} x\ 100\% = \frac{51,77-49,71}{551,7-48,9}\ x\ 100\% = 71,77\%$$

2. Massa cawan kosong = 48,9 gr

Massa cawan + sampel basah = 50,90 gr

Massa cawan + sampel kering = 49,78 gr

Sehingga

$$kadar\ air\ (\%) = \frac{(w1-w2)}{w1-w0} x\ 100\% = \frac{5150,90-49,78}{50,90-48,9}\ x\ 100\% = 56\%$$

% Kadar air $= \frac{71,77+56}{2} = 63,88\ \%$

b. Menghitung Kadar Air Ubi Kayu Selama Proses Pengeringan

Waktu = 30 menit

Massa cawan kosong = 25,56 gr

Massa cawan + sampel basah = 25,56 gr

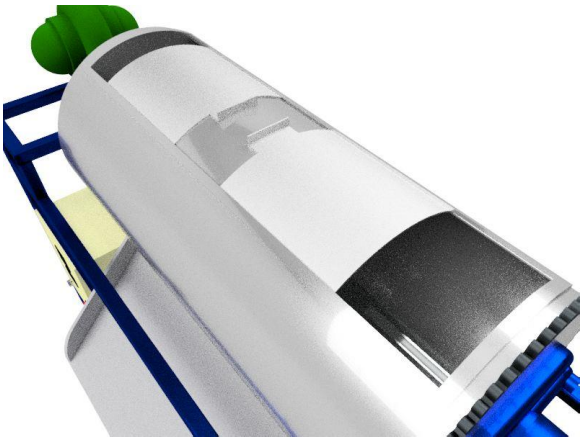
Massa cawan + sampel kering = 26,4 gr

Sehingga

$$kadar\ air\ (\%) = \frac{(m_2 - m_1)}{m_1} x\ 100\%$$

$$kadar\ air\ (\%) = \frac{(2 - 0,8)}{6,72} x\ 100\% = 60\%$$

LAMPIRAN C
GAMBAR ALAT DAN DOKUMENTASI



Desain 3D *Rotary Dryer* Tampak Depan dan Tampak Atas

GAMBAR

Ubi Kayu Segar yang
Telah Dikupas

Proses Penimbangan Ubi Kayu
Setelah di kupas dan dicuci.

Proses Pemotongan Ubi Kayu

Proses Fermentasi Ubi Kayu.

Proses Pengeringan Ubi Kayu

Proses Pengeluaran Ubi Kayu Kering.

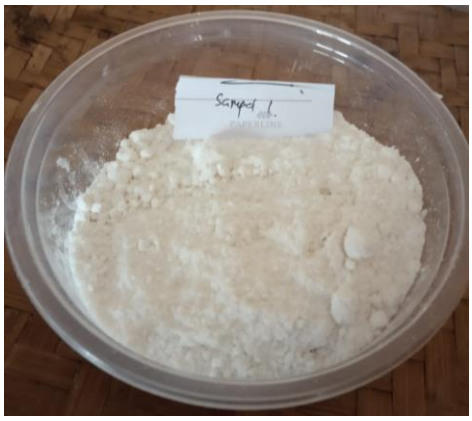
Setelah di Fermentasi

Proses Penimbangan Ubi Kayu Kering

Hasil Ubi Kayu Setelah Pengeringan

Proses Penghalusan Tepung Ubi Kayu.

Tepung Ubi Kayu Setelah Dihaluskan



Proses Pengayakan Tepung Ubi Kayu Tepung *Mocaf*