Freezing of fruits and vegetables

An agribusiness alternative for rural and semi-rural areas

FAO
AGRICULTURAL
SERVICES
BULLETIN

158

by
Gustavo V. Barbosa-Cánovas
Washington State University
Pullman, Washington, United States of America

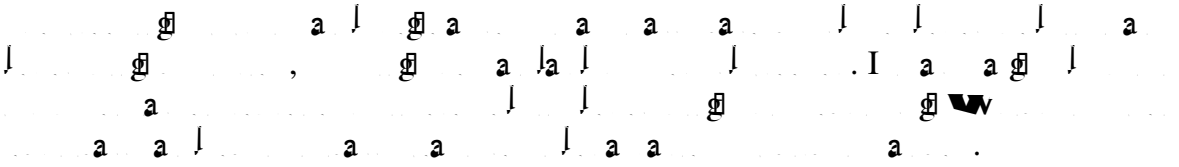
Bilge Altunakar
Washington State University
Pullman, Washington, United States of America

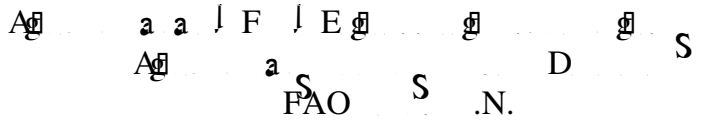
Danilo J. Mejía-Lorío
Food and Agriculture Organization of the United Nations
Rome, Italy

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2005

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

ISBN 92-5-105295-6





H– F–
IIR
I c

I F
L I
L ca fr ra –

a r c d F d

r a r r f

c a

da

r fr a

r ra

r ar ac a

c fr

S c dar ac a

C a 1

F ... , 2000).

1.1

F ... (F a, 1977). ...

F ... -18 C (F a a, 1973). ... (G , 1993).

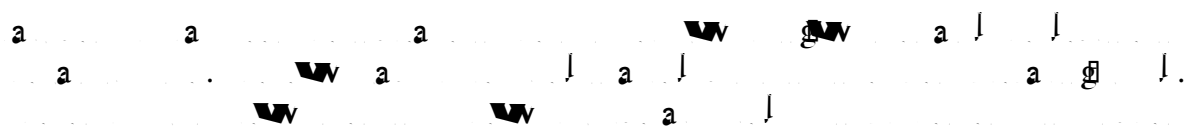
C ... (A , 1993). ... (H a Ka , 1975).

– rr a ffr f d d r _ S a d r c r

. I , $ 75 . E . $ 27.3 2001 (AFFI, 2003). I E , . , $ 11.1 13 $ 2000 (Q F F I , 2000). 1 2001.

Ad a a ffr c d c r

D , ., $ 7 $., 01.



Early years

(A , 1993).

1869

1929.

1940 .

2001

3.

1905 (D , 1977).

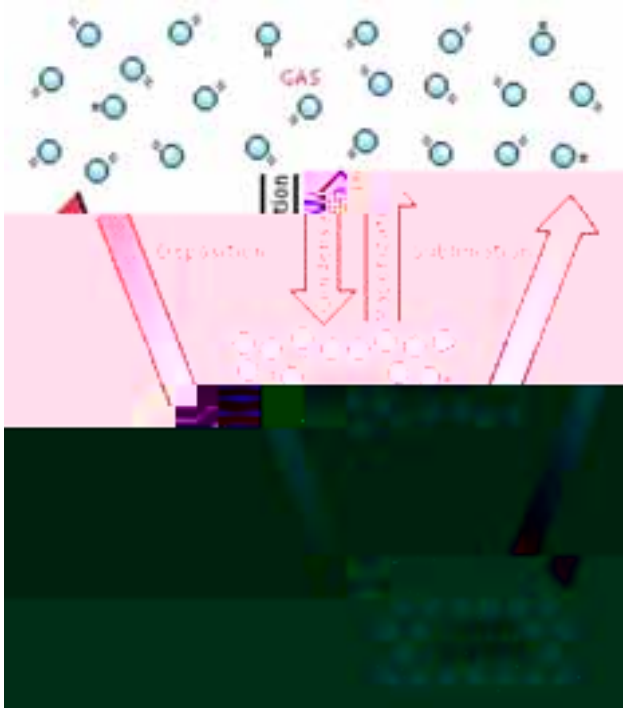
Further development

, 1977).

1.2

F
, aa

Fg 1. A c a c ra f ra fr r c



(L , 1979).

(P L , 1993).

(P L , 1993).

F

(P L , 1993).

- D
- I
- S
- C
-

G

a 4. – ff c a d R f E a

Geome r	P	R	Dimen ion
Infinite slab	1/2	1/8	thickness e
Infinite cylinder	1/4	1/16	radius r
Sphere	1/6	1/24	radius r

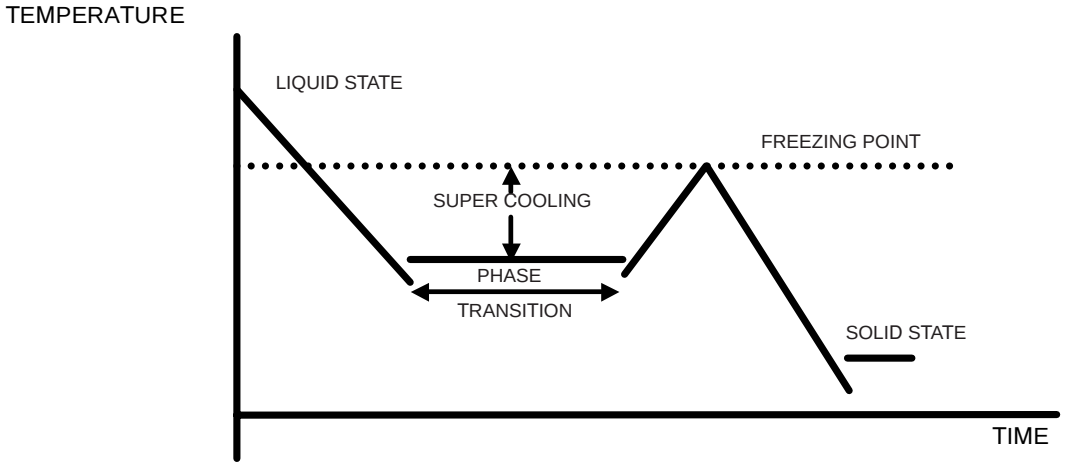
$$t_F = \frac{\rho\lambda_l}{T_F - T_e}\left[\frac{e^2 R}{k} + \frac{eP}{h}\right] \quad (1)$$

a l W a g l a (Pa , 1980).

λl a a a , a l ρa a l a l l a W a a . l l a l W l l a W a a a l Pa g a 4a l a a g l a l g g l W l l (. . a g , a a l l a l W l a l l).

A l a , a Pa a l a a g a a g g g . H W , l a a a a g a g a . a g l a a l a Pa a l l l l , a l a a a g a (Ba a -Ca a a l I a , 2002).

Fg 4. Fr r r a d a c c r



, a a (a , 1999). 4 a a

a S a a , a a ,a a

$$\Delta H = \left[1 - \frac{X_{SNJ}}{100}\right]\Delta H_j + 1.21\left[\frac{X_{SNJ}}{100}\right]\Delta T$$

(H a K , 1996).

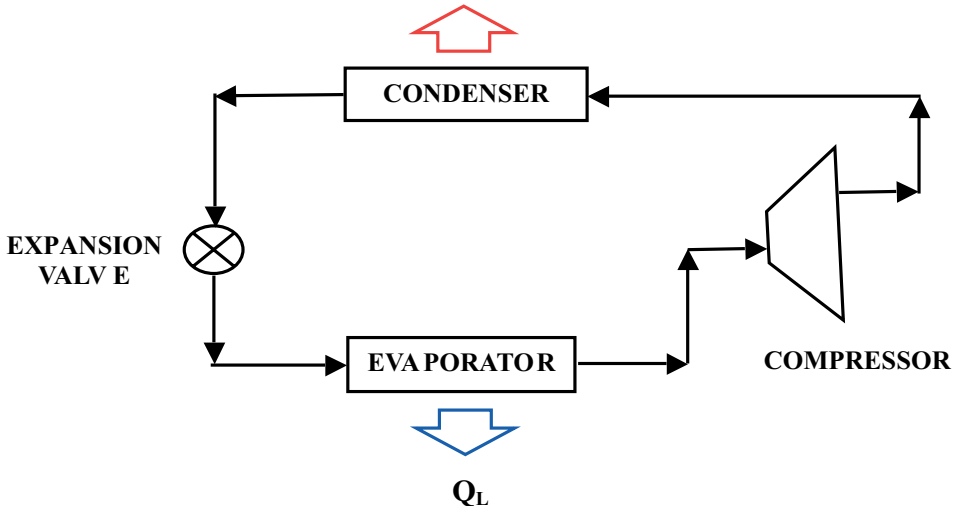
F a a a a a a (1949) a a a .

NJ: P ag (D a)
ΔH : E a a g g a
Δ : a a a a

1.2.3 Ref ige a ion

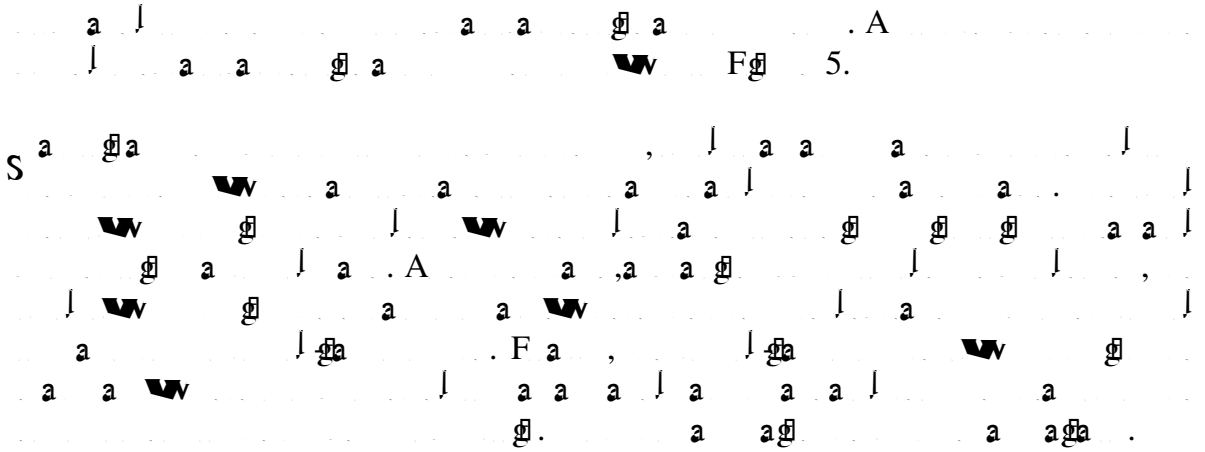
g a a a a a a a a a a
g a a g . a g a a
a g a g g a a a
g . A g a , a
g a , a a a a
g a , a . a a
g a a a a a

Fg 5. A c f r a a c d c a ca r fr ra
Ada d fr S c r F a d R fr ra a d Ar – d
c ra H r



. F a , a a g a
g a a , g g
(LIN) a (CO2),a .

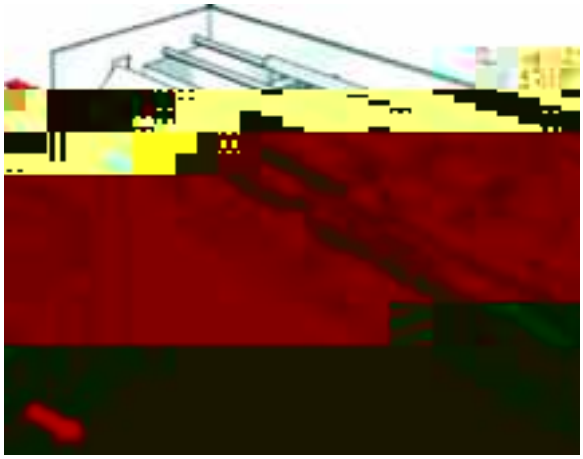
a a a a g a a ,
, a a , a a a . g a
a (HCFC) a a a a g a



1.2.4 Feeding capacity

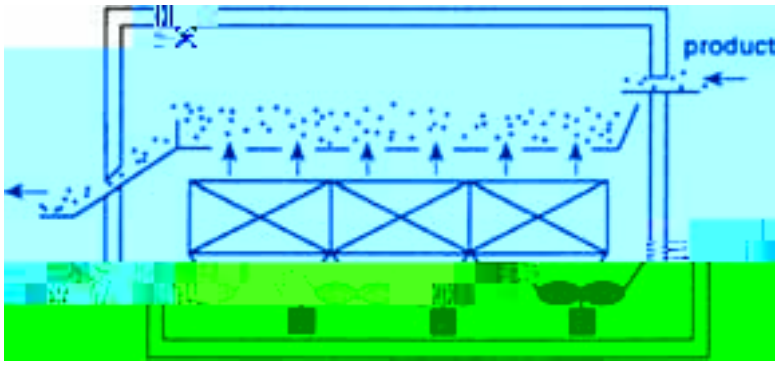
1.2.5 Feeding time

Fg 9 . – r c a f a f d d d fr r
– r f Fr ca d a E L d –



a a l a l g a l a a g a a ,
a g l W a g l l g l ,a -
a . C a a a l
a a g l l W a g , W l a l g
. W a - a W a
l , a a a l g W a W
l , g a g a a l a .
a a a a l a a
a l l a . O - a l g a a
, a .

Fg 9 . S r r c f a f d d d fr r
Sara ac ar A E



T[illegible] fr[illegible] r[illegible]

I[illegible] (M[illegible], 1993). A [illegible] Fig[illegible] 7.

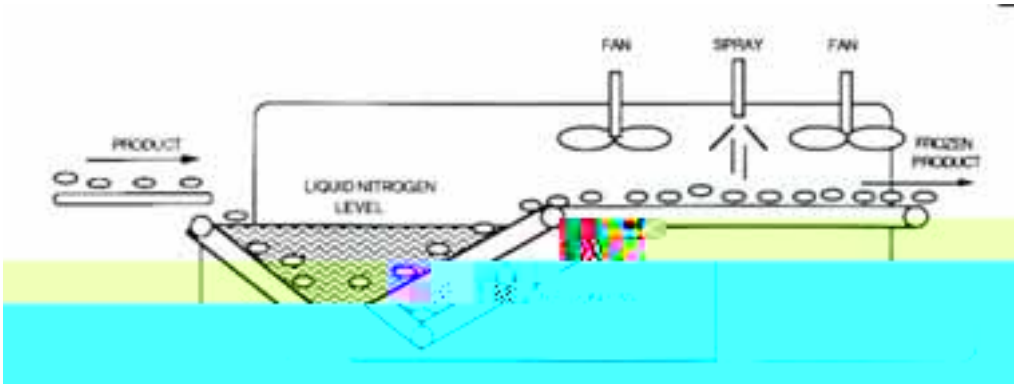
B[illegible] fr[illegible] r[illegible]

B[illegible]. A [illegible]

[illegible]. A [illegible]. I[illegible]

, a a - a a a (a a , 1999). a

Fg 11. S ra f a ca r fr r F

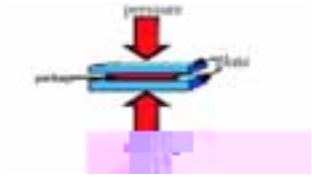


Fg 12. I d r c c ac fr r

, a a (G , 1993). a a , a a .

a a a a a (IQF), a (P a L a , 1993). a a (IQF) a a a

Fg 13a . r r a ca a a fr r



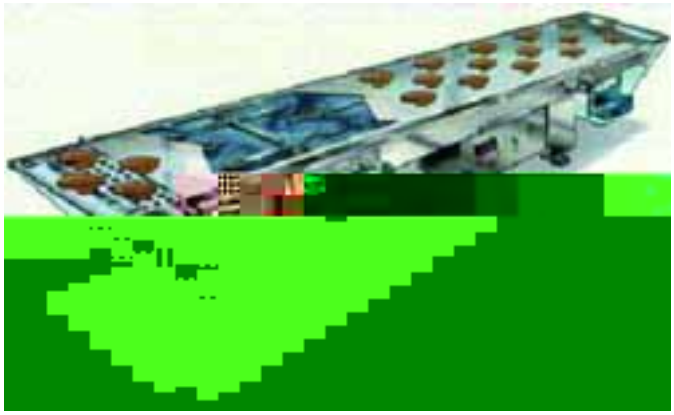
g . l a a g a a w a g l g IQF g . S a g a , w , , - l a , l l a , a l a l w w g . A a l l - l w Fg 9a a l 9 .

Fg 13 . a fr r a a c r r a d a a r c d r – r f SI Sa f Fr r S r I

C a g wa g a a a . I g, l a l l a w g l . F l a , l g l l g l , g a , a g a a . A a a g Fg 10. F l a , l l l g l w a w a w a w g l (Ma , 1993).

I r fr r

Fg 14. – **ac fr r**
– **r f Fr ca d a E L d –**



K , 1996). D

I , (G , 1993). A Fg 11.

I d r c c ac fr r

I Fg 12. I

a ag l l l a a ag a a . Al l a ,
a l a a a ag v a a a .

a fr r

a a . I a , l
l v a v a a , a a , v a
g a a g l a . P a l g l a a
a a v Fg 13a .
g l g a - a l a a
a - a l a ag l l . A a a v
Fg 13 .

– ac fr r

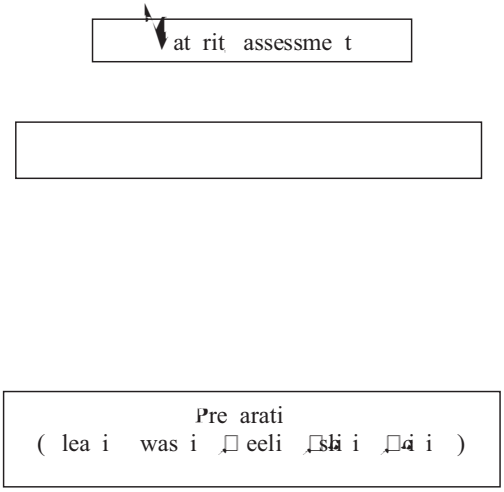
l g v g - a l l - a l g
l a a v Fg 14. l g a a g v a l
l . a l a , , gg , a a l
(P a l L la , 1993).

C g g a a v l g v l l
a a v -60 C g l a v l ga a
g a l l (H g a l K , 1996). l
g l a g a a ; g a
l a l a g l a a a a l l l - g
a . , a a l g
a v l g a l g a a . I v a
a l a g a g a a g (P
a l L la , 1993).

L d r fr r

L l g v a g a -196 Ca a , a -
l g a a . g a a l a l
2a a , a l

1.2.7 Packaging


Raw materials
at rit assessme t
Pre arati
(lea i was i eeli shi i i)

1982). N - l a l ag a l a l - a - a
a a , a a l a . Ba a
l a ag a a a l a l l a l
a a l a C , 1993). a l
a l a l a ag a a .

S a a l a a a a l l
a a l l a l l a l
a l l a . F a a , a
99 a a l aa - a a

1.3.1 F ee ing f i

g, ag , a ! w g a a

C a a a . I , a a a

1978). 30-60

1968).

Fruit	Preparation	Method of Packing
Apples	Wash, peel, and slice into antidarkening solution -- 3 tablespoons lemon juice per quart of water	Pack in 30-40% syrup, adding 1/2 teaspoon crystalline ascorbic acid per quart of syrup. Pack dry or with up to 1/2 cup sugar per quart of apple slices.
Apricots	Wash, halve, and pit.	

P a l l g v g , ,
a l a . P a a l l g 1 v l l v 1
v a . l a l l 1 ; 1/2 g a l l l
a l l l ; l l v v a l l v a .
P a l a 4 6 a v a l g
a l l l v a . a a l a l (Ba l ,
2002).

S ar ac

I a g a g a a , g a l . a
a g a l g l v a l g a l l . a
g a l l a a , v , , a l
, g v a a
a v g a g (B , 1996).

l ac

v l a a a l a v a , l - a l , v
v a a g a a l , a l v l . v a
l a l g a a , g l g a a l
v a - a a a . G a , v l a l a v a l
v a v g a a v , a a ,
, a l l a , g , a , a l a a a g l
a v g a (B , 1996).

Tra ac

v l a a g a a l g a a v a g a
a l a l a v a , , a l a a g l a g
. a v g g v
a l a a g g .

S ar r ac ac

A a v a a l a l g a .
v a g a a a l g l v , v
a g a a l a a l .
F v g a v a l a l v v a
v g a (B , 1996).

1.3.2 F ee ing ege a le

F g l l a l a a v a a
g a (Ga , 1996). F g a a l a a g a
a l (Ma , 1993). a

[illegible]

[illegible] (G[illegible], 1996):

- S[illegible]
- E[illegible]
- H[illegible]

A[illegible] (H[illegible], 2004).

A[illegible] (A[illegible], 1993). [illegible] (L[illegible], 1989). M[illegible]

e e e	P/e r ion	n /ee e
Asparagus	Wash and sort by size. Snap off tough ends. Cut stalks into 5--2q1Tf0.74 03.49D0.0027 (04 1 Tf 0.8949 0 40.0019 Tc (ut)-27m1(nt1 nT q 1Tf 6.4 0))10J787	

(L , 1989).

(D a , 1977).

B a

(D a , 1977).

(H , 1983).
(D a , 1977).

(A , 1993).

(A a , 2003).

[illegible]

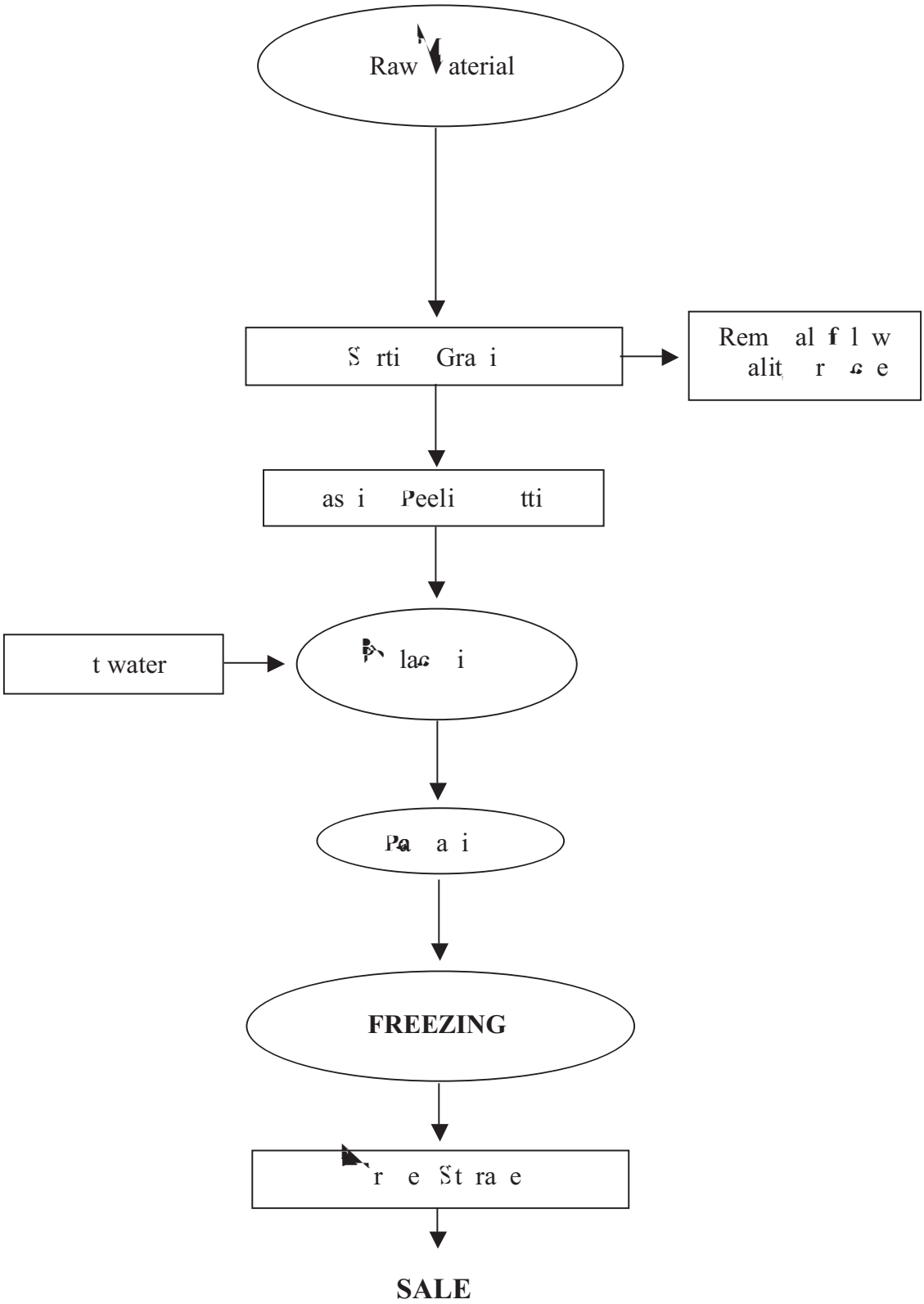
G [illegible] a [illegible] a [illegible]

.1 [illegible]

O [illegible] Fg [illegible] 16. [illegible]

Fg [illegible] 16. **Ra [illegible] rr [illegible] a [illegible] d [illegible] ac [illegible] rr**

Fg 19. F d a ra ffr r c f a a d r d c



I a . S
(H , 1968). A 18a 19

2.3.1 oca ion

- A a , , ,a ,a
- F a a a a a a a .

2.3.2 Gene al plan la o

- P a a ( ) a a
- a a a .
- a , a a , a .
- a a - a (a)a a a a a a a .
- D a - , a .
- Ea - a a . P a .
- A a a a , a a a a a a a .

E (H , 1968).

C[illegible] 3

[illegible]

3.1 [illegible]

[illegible]

- F[illegible]
  [illegible] (40 [illegible])
- [illegible]
  G[illegible]

3.[illegible]

A[illegible] 1 000 [illegible] CF146 [illegible] 414 [illegible] 20.

Fig. 20. a – F c fr r r a f

7 7

[illegible]

7.

[illegible]

C a a a 30 Ca a a . a a a a a a . H , a a - a a a a a (J a , 1994).

Ca 4

1991).

, 1996).

4.1.1 Ph ical a pec of f ee ing

M ... (P a a M , 1997).

T r

M ... 90 ...

C ...

D a g a a g a a , a a a g a a a a a g , g , a a a (M a a g , 1993).

cr ca a c f fr

M g a g a g , a a g a a g g a g a a g g (A

. Ma a a a , a a a

F l g a a , a a ag a :

r Fac

g ¾ (85g)

S g S P C a 5

S A g

Ga 25 Ga a 0

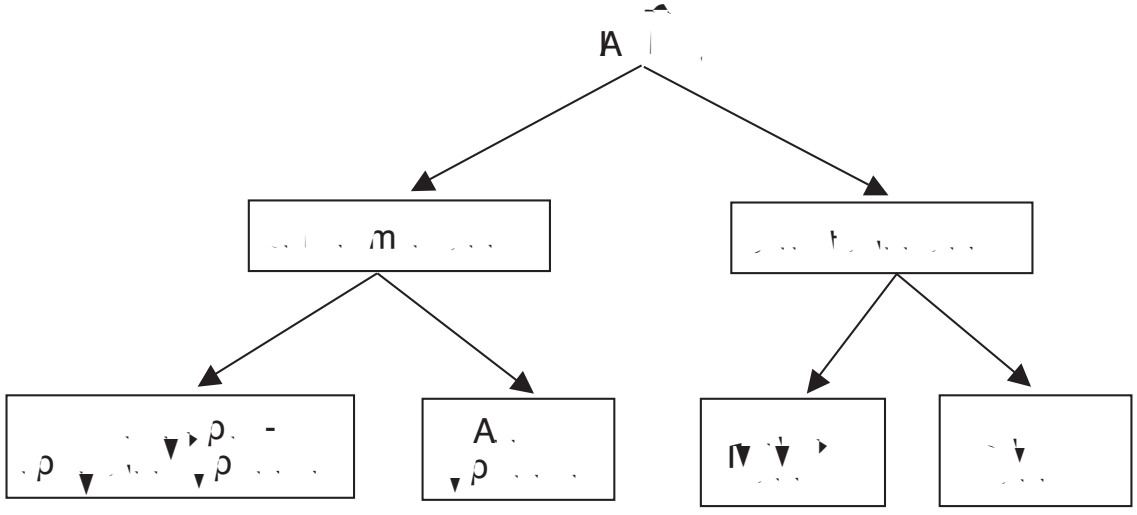
% Da a *

Table 7. – [illegible] for [illegible] and [illegible] *et al.*

[illegible]	[illegible]
[illegible] (10 [illegible]):	
A[illegible]	3 [illegible] 5 [illegible]
[illegible]	1/2 [illegible] 2 [illegible]
B[illegible] [illegible]:	
B[illegible]	20 [illegible] 30 m[illegible]
[illegible]	5 [illegible] 10 m[illegible]
[illegible]	1/2 [illegible] 1 m[illegible]

F.1 [illegible]

[illegible]:



- 1 000 g/ .

5.1.1 n e men co

A ... , ... , ... , ... , ... , ... , ...

- : ... . C ... , ... $ 250 ... (... , ... ,

a 9. E a f a c f r fr a

e o				
e		n i	ni Co	o Co
-	K	1	250.00	250.00
D		1	100.00	100.00
D	F	1	600.00	600.00
		1	300.00	300.00
		-	150.00	150.00
			O AL	$ 1 400.00

r ra c _ S
A c _ S
I c _ S

ar a c
a a a g a .

_ a a ;
_ a g a ;
_ a (a , , , g a a ,);
_ a a a a ;
_ a g ;
_ a a a g .

F dc

F a a a a a a a . E :

- a ;
- a a a ;
- a a .

1. Ga a a : C $ 300 ( ) a a . a $ 600 a a .

2. C a a a a a a , . Ba , a a a ,a a a a a :

P a :	1 000 a (2 000 a a);
F a a :	40 20 ;
a a :	500 a ;
A a :	$ 0.10/ ,
P :	1.5 500 = 750 / ; 750 a $ 0.10/ = $ 75/ .

3. Ga a W a a a 100 g .

R m e/i n ie 100 e e e

R e/i	n i	ni Co	o Co
C ( )	25	1.25	31.25
G B ( )	25	2.50	65.50
O ( )	25	1.25	31.25
C ( )	25	2.00	50.00
( )	500	0.01	5.00
P M	200	0.05	10.00
		O AL	$ 193.00

4. Ga a W a a a 1 000 g .

W a a a : $ 193 10 = $ 1 930.00
La : $ 600.00
E g : $ 75.00
T a ar a c $

F d e : a

1. Ga a a :

A a a = a / 8
M a = A a a / 12

a a = $ 1 400.00
A a a $ 1 400 / 8 = $ 175
M a $ 175 / 12 = $ 14.58

2. G a a a l a :

D a :		$ 14.58
A l a :	S	$ 425.00
T a f d c	S	

a a a :		$ 2 605.00
a l :	S	$ 439.58
T a r d c c	S	

Ga a a d . P a
1 000 g / a 500 g g a a ag a a .

(a ag) = $ 3 044.58 / 2 000 = $ 1.52

a a a $ 3.20 g a .

E a a a a a . E a a a a g
w g a :

M = F / (a a)

a a : a a a / 2 000

ar a – r ac a – S

M = $ 439.58/($ 3.20 - $ 1.30)
M : 232 a ag

I , 232 a ag 2 000 a
a .

AFFI 2003. A a F F I ,
(a . /a a - a) : NPD, G , I ., F
I , F F Agd , I I, Na a a A a , , I ,
a A a .

Arc r d – a d A 1995. a
gd a a a - . I a a
J a F a gd . 30, . 711.

Arc a 2003. F gd gd a G E-320. N M a ,
gd Agd a H E E .

Ar 1993. F gd gd a a . I : Ma , C.P. ., F F
gd C a a a Ha , L , K.

ASHRAE Ha d , 1994. gd a a A a , A a
Ha gd, gd a gd, a A - gd E gd , A a a , GA,
A.

Bar a – a a a d I ar A 2002. O a F E gd gd.
C C P , B a a , FL, A.

B a ard a d Fra F 1987. I a a a -
. F a a , Aa P , L , K,
. 51-65.

B dr AE 1981. F a a a . N a F I , Na g g . 19, . 24.

B F a d f rd ER 1968. aa g a g , F g P a F , 3, 4 ., A I , C , A.

B F F r B a d f rd E R 1977. F g . I : D , N. ., , D.K. , F a a F F g. A P g I . , A. . 135-215.

Br d A 1982. Pa Ma a . 4 ., B w , L , K.

– a ad a F d I c A c La 2004. P a a P C a , F a D g g a , C. .C., 870 (w . g .a/ g / g/ g .).

– a a d ar A 1992. Pg a a a w . J a Agg a F C . 40, . 2141.

– a 1996. g a , F g E Qa , Ma D , N .

– a ar A a d F r – 1990. F g a a a , I a a a a g. J a F S . 55, 4, . 1070.

– – 1985. a a a g a w g a a a a . J a F S . 50.

– a a d a d – a a d A – 1987a . P g a w g -a a a . Pa :1 g a a . I a a J a g a . 10, . 156-164.

– a a d a d – a a d A – 1987 . P g a w g -a a a . Pa : 2 I g a a . I a a J a g a . 10, . 234-240.

ad A E a d S 2000. Ha a a g g ,a w . J a F E g g . 47, . 157-174.

r r a d r r . 1977. P F l F g, g F l F g, 4 l., A I P g C . I . C , S A.

r r a d Tr r 1977. F l a a F l F g, A I P g C . I . C .

r c – R L a H a d B 1959. - a a l. III. E a g l a a , F l g , 13:258.

SI Sa f Fr r Sr I I a (w w l a .).

E c a R a d r c R 1977. F F l , P F l F g, g F l F g, 4 l., A I P g C . I . C , S A.

F 2000. F l g g , a l a . C C P , B a a , FL

F a 1977. L a a l l . F l g , 12:32-38.

F a R 1973. w a P a l a l g a . F a , O. ., N w , . D., Ma , E. H., E l , P , N w , C . 3.

Fra F 1985. B a l a w a , Ga lg P , Ga lg , K. . 21.

Fr ca d a L T (w . l . /FMC).

r R 1993. F g l l l . l F l a l g . 4, . 134. S

c d 1968. P g a l w a ag , w a a a l g a , L w a B g F l , A l a F l , 4, P g a P , L l . S

rad H 1988. ag , a a l a g

a a a . D A I B48:9.

Harr R S a d ra r E 1975. N E a a l P g, 2 l l. A P g C. , S A.

Harr a d – r c r 1993. Pa a g g F F l, F F l g (Ma CP l.) C a a a l Ha , L l , K.

H rr T 1968. C a g g a l g a a g F F l P g Pa , H g , A a a , 23 l a A . S

H d r S 1983. P a F a l g a F l P l , Ma a P , L l , K.

H H a a a S ra a E rr a d 2004. Ha l g a P a a l P g. Ma D , I .

H – a d 1996. F l a a a - a g. F l 50:59.

, 14:549.

a – 1993. F F . C a a H a , L , K.

a T a d T 1993. P a F C , F F (Ma CP .) C a S a a H a , L , K.

c a S a r E 1999. C a . P F S a (. . / / / 01/01600506.).

ad A 1978. E , a a a a . F Q a a N , A S P L . L , K.

a a a Ta S a d H a S 1955. E a - a , P . 9 I C , Pa , Fa .

r a d L da 1993. F , F F (Ma CP .), C a a H a , L , K.

a T a d a R F 1977. M a I a a F F . I : Q a F F , E , M. C., H , ., E . C a a H a , N

a R 1980. E E F a I a A a , Ba a: .

c Fr F d I r a a 2000. G a F F A a a , 33, N .2.

Ra a S 1999. H a F P a , Ma D , N , S A.

Ra a a H S a d T A 1984. A F . J a F P E . 7, . 169-203.

R d L 1949. C a E . 21, . 340.

R r L 1985. C a a F C , . 17, . 25.