AN INVESTIGATION OF A CONTINUOUS PROCESS FOR THE FLASH DRYING AND GRINDING OF ALFALFA

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Clyde G. Anderson

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This is to certify that the

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presented by

CLYDE G. ANDERSON

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AN INVESTIGATION OF A CONTINUOUS PROCESS FOR THE FLASH DRYING AND GRINDING OF ALFALFA

By

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INTRODUCTION

This investigation of the flash drying of alfalfa had two objectives; first, to determine the capacity of the pilot plant and the limiting factors on the capacity; second, to determine the effect of this method of drying on the retention of carotene in the dried product.

The flash drying of alfalfa is accomplished by introducing hot flue gases directly into the grinding chamber of a hammer mill where a large percentage of the drying occurs. As the alfalfa is reduced in size, a large area of wet surface is exposed to the hot gases entering the mill. Exposure of this surface enables the rapid drying of the alfalfa. Further drying is accomplished in the elutriator and cyclone.

In the second phase, antioxidants were mixed with the green feed to determine if the amount of carotene retained in the product could be increased.

The number of antioxidants used was limited to four, which were known to be good inhibitors to the destruction of carotene in alfalfa meal. The antioxidants were selected from those used by C. Ray Thompson[1] in his work on alfalfa meal.

Artificial drying of alfalfa is of particular advantage in that the crop can be harvested early in the season

when its food value is the greatest. Late cuttings have a high content of indigestible wood fibers, low carbohydrate, protein, and vitamin content. Instead of leaving the alfalfa reach this condition more frequent cuttings can be made and dried, thus retaining the food value of the feed.

HISTORY

Work was begun in 1950 on a process for the simultaneous grinding and drying of alfalfa by Wilbur W. Kennett[2]. His work was limited to the mass transfer and mass transfer coefficients while drying and grinding alfalfa. The equipment at that time necessitated batch operations as there was no method of recycling part of the ground and dried meal. It was found that green alfalfa of 80% moisture clogged the mill and it became necessary to mix dried meal with the green feed to bring the moisture down to at least 35% before the mill would continue to operate without clogging. In the initial operations this was accomplished by mixing dried meal with the green feed and then introducing this mixture to the mill. Redesign and addition of equipment enabled the recirculation of coarse meal to the hammer mill where it was mixed with the green feed entering. Further discussion of this will be made under "equipment".

To the author's knowledge, there is no commercial application of the type of equipment used in this investigation to the drying of alfalfa. Other types of driers of the drum and conveyor type are being used in commercial driers. In these type driers the alfalfa is dried as it comes from the field. No attempt is made to take advantage of the more rapid drying rates obtained when the alfalfa is ground and a large surface area exposed to high temperature gases.

Considerable work has been done to determine the cause of the breakdown of carotene. In 1928 Bohm and Haas reported that seeds of legumes contain an enzyme which had the ability to oxidize carotene and unsaturated fats.

Tauber describes an experiment proving that a carotene oxidase does not exist and that the oxidation of carotene is caused indirectly by an "unsaturated fat oxidase". Results of this experiment show that the oxidation of carotene is dependent on the simultaneous oxidation of unsaturated fats(3).

Further work by H. H. Strain proved Tauber's theory(4). Carotenoid pigments or Vitamin A present in unsaturated fats are oxidized by intermediated products, not by direct enzymatic action, nor by the relatively stable "fat perexides". The unsaturated fat oxidase has been detected in various legumes including alfalfa. The oxidase has been found to oxidize only those compounds containing $-\overset{H}{C} = \overset{H}{C}\ (CH_2)_7C(O)$-group with Cis-configuration. For example oleic, ricinoleic, linoleic, and linoleic acids and their esters absorb oxygen very rapidly.

According to work by Silker(5), blanching fresh green alfalfa with steam prior to drying furnished complete protection for the carotene. Also considerable protection was afforded by certain antioxidants applied to fresh ground alfalfa. The above work was done on a tray drier at 65 degrees centigrade. Silker also reports that grinding is detrimental to the retention of carotene. This is due to the large amount of surface

exposed for the oxidation to occur in.

C. Ray Thompson[1] has done considerable work on the use of antioxidants to stabilize the carotene in alfalfa meal. In this work he used alfalfa meal which had been previously dried. The meal was treated with various antioxidants and solvents. The samples were stored under controlled conditions for seven and fourteen days at 65 degrees centigrade to promote the rapid deterioration of carotene in the meal. The samples were then analyzed for carotene content.

Of the 54 antioxidants used in Thompson's work, 2,5 di-substituted hydroquinones, p substituted phenylene-diamines and 2,2,4 trimethyl-1,2-dihydroquinoline were the most active compounds tested for stabilizing carotene in alfalfa. Vegetable oils plus acetone were superior to alcohols, cellosolve, or kerosene as carriers for the antioxidant.

EQUIPMENT

The equipment used in this work is as follows:

McCormick Deering Hammer Mill No. 4-e complete with meter.

Specifications for hammer mill

Speed, full load	2980
Diameter of rotor-hammers extended	12 in.
Power	5 H.P.
Grinding plate area	123 sq. in.
Screen area	148 sq. in.
Total grinding area	271 sq. in.

Blower fan 1 3/8 in. dia., 5 wings 3/16 in. wide

Pipe size 4 in.

Cyclone dia. 14.5 in., overall height 36 in.

Hay chopper

Elutriator

Surface combustion burner using 35 psi using propane

Temperature recording galvanometer

Chromel-alumel thermocouples

Westinghouse type T.A. Industrial Analyzer, P.F., volts, amperes, and kilowatt meters

Scales to weigh feed used per run

Chainomatic analytic balance CM 554

Drying oven 120 degrees centigrade

Spray gun for applying antioxidant

Equipment for analyzing for carotene

High speed agitator

Cenco analytic balance

Refluxing equipment (condenser and erlynmeyer flasks)

Buchner funnel

Separatory funnels

100 ml volumetric flasks

Photometer

Filters #243, #396, #554

Chemicals required for analysis

Acetone

Petroleum ether

$Ba(OH)_2.8H_2O$ and NaOH solution

90% methyl alcohol-saturated with petroleum ether

$(Na)_2SO_4$ anhydrous

Photograph 1

Photograph 1 is an overall view of the equipment used in this investigation. The furnace with burner is shown in the foreground with mill directly behind. Directly above the mill is the elutriator which separates the coarse material for recycle from the fine meal which is carried over to the cyclone. The meal settles out in the cyclone and is collected in sacks attached to the bottom of the pipe below the cyclone. Gases from the cyclone are carried through a stack to the roof of the building. Exhaust fan is shown in the background to the left, and temperature recorder to the right.

The furnace is covered with asbestos to prevent loss of heat. The amount of excess air is controlled by removing bricks from the front of the furnace. Baffles were installed in the furnace to shorten the flame length.

Photograph 2 is a close up view of mill with top gas inlet from furnace to mill. The strip of sheet metal with the slot in it, which is shown in the front of the shield around the mill, is a damper control for regulating the size of the opening of the bottom gas inlet to the mill.

The hay chopper with motor and gear arrangement may be seen in back of the mill. This hay chopper was made from a lawn mower, and was used to cut the green alfalfa into short lengths.

The thermocouple terminal bar is shown attached to the shield around the mill.

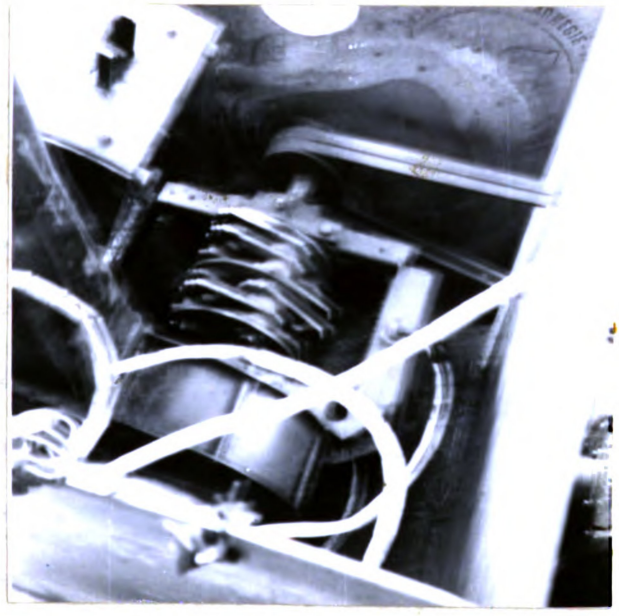
photograph 2

Photograph 3 is a view from the hopper side of the mill where material is fed into the mill. Above the hopper may be seen the arrangement used to maintain a seal at the bottom of the elutriator. By regulating the hinged door, enough recycle was kept backed up to prevent gases from being blown out at this point.

In the background, upper left corner, the drying ovens for determining moisture content are shown.

Photograph 3

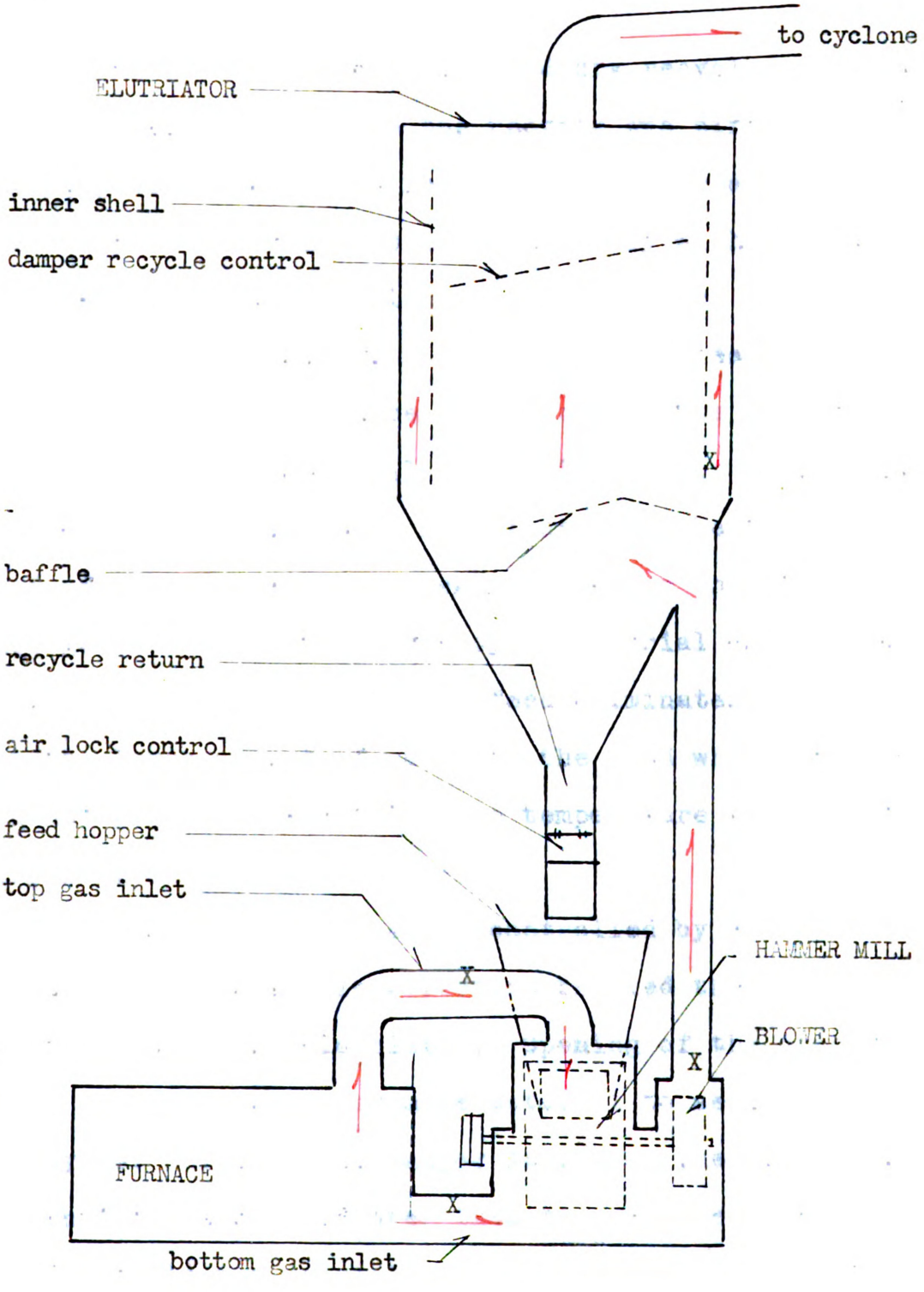
Photograph 4 is a view of the hammer mill when opened up. The hammers and screen may be seen. In front of these is the blower. The white lines are thermocouple leads.



Photograph 4

The following diagram illustrates the design of the equipment. Gases are pulled through the furnace by the blower fan. Part of the gases pass over the top, directly into the hammer mill. The rest enters through the bottom inlet below the hammer mill screen. The amount of gas entering the bottom was controlled by the damper shown. The feed mixture passes through the screen and is carried up into the elutriator where it strikes a baffle which distributes the meal in the elutriator. A reduction in gas velocity allows the coarser material to settle out and be recycled. The finer meal is carried up through the elutriator to the cyclone. By varying the position of the "damper recycle control", the velocity of the gases is varied and the size of the meal which can be carried over is controlled.

DIAGRAM OF EQUIPMENT SHOWING FLOW OF GASES



X's mark the location of thermocouples

PROCEDURE

WITHOUT ANTIOXIDANT

The mill was started cold, and dry recycle material was fed into the mill. When the recycle was circulating smoothly, green alfalfa was fed to the chopper and then to the mill hopper where it was mixed manually with the recycle from the elutriator. Recycle and green mixture was then fed into the mill continuously. As soon as the green feed began entering the mill the furnace was started. The feed mixture was fed slowly at first until the equipment got up to heat - about 7 or 8 minutes. It is important that the furnace be started after the green feed begins to enter the mill since the hot gases hitting the dry recycle material can ignite this material. The presence of green feed eliminates this danger due to the large amount of water in the feed which is vaporized by the hot gases, thus cutting the temperature to a point where the dry meal will not be ignited.

The amount of recycle was controlled by a damper effect on the elutriator which in effect controlled the velocity of the gases through the elutriator. Opening of the damper cut down the velocity, allowing more material to settle out, giving more recycle. Closing the damper increased the velocity, thus more material was carried over into the cyclone. An air seal of dried recycle was maintained at the bottom of the elutriator.

This was controlled by hand operation by the person mixing and feeding the alfalfa into the hammer mill. A fairly constant feed rate was maintained by noting the load as indicated by the power analyzer and regulating the feed rate to maintain a constant load.

Temperatures of gases entering hammer mill and leaving the blower were noted during the run, and the furnace was regulated to maintain the temperature.

Fifteen to 20 pounds of recycle appeared to be the ideal amount of material recirculating. When smaller amount was used, the operation was not smooth and it was difficult to maintain a seal at the bottom of the elutriator. The smaller amounts of recycle used in some of the runs were used so that the recycle material would have less effect on the carotene in the product.

The rate of recycle was determined by drawing off a sample for a measured length of time and weighing this amount. Care was taken to have the recycle operating smoothly while drawing the sample. The weights of green feed and recycle introduced were taken before the run. Time to make the run, temperature of entering and leaving gases, and the power used, were noted during the run. At the end of the run, the weights of product and recycle left in the mill were recorded. Samples for carotene analysis were taken at the end of the run and placed immediately in cold storage at 3 degrees centigrade.

At the end of a run it is necessary to shut off the furnace and mill immediately. Failure to do this within a minute or two would result in the dry meal being ignited. Even after the furnace is shut off the fan in the mill pulls enough heat from the hot walls of the furnace to cause ignition of the dry meal. Therefore the mill was shut off at the same time as the furnace and allowed to cool before cleaning in preparation for the next run.

PROCEDURE WITH ANTIOXIDANT RUNS

The alfalfa for the run was first chopped into lengths that averaged one inch. The material for the whole run was then sprayed and thoroughly mixed with the antioxidant. Enough antioxidant was applied to make the concentration of the antioxidant 0.25% of the feed on a dry basis. The prepared alfalfa was then run as described above and samples taken and stored in a refrigerator until the analysis of carotene content was made.

Preparation of Antioxidant

A solution of 100ml of soybean oil and 100ml of acetone was made. To this, 10 grams of antioxidant were added. The resulting solution thus made up contained .05 gm/ml. The weight of the green alfalfa was taken and the weight on a dry basis calculated. Enough of the antioxidant solution was sprayed on the alfalfa to produce a concentration of 0.25% antioxidant.

PROCEDURE FOR ANALYSIS OF CAROTENE

Methods of analysis for carotene are not exact. In this work two analysis of each sample were made and an average taken. Because of the lack of stability of the carotene, the samples were stored at 3 degrees ~ until analysis were run. All analysis in this work were run within a week after the material was dried.

A phasic separation was used to purify the caretene solution in preparation for indexing on a colorimeter. Filters #243 and #396 were used to determine the Chlorophyll correction to be applied to the readings using a #554 filter. The colorimeter had previously been calibrated against standard solutions of known carotene content. Comparison of the sample readings with the readings obtained with standard solutions enabled the determinations of carotene content of the sample.

The method used is the same as that used by the Agriculture Experiment Station at Michigan State College. The colorimeter and conversion charts used were those of the above experiment station.

A detailed procedure of the method of extraction and purification of carotene from the alfalfa sample is as follows:

CAROTENE ANALYSIS IN ALFALFA

Extraction from fresh alfalfa:

Weigh out a 4 gram sample and place in a Erlynmeyer flask. Add 85 ml of undiluted Acetone and agitate vigorously for 4 minutes. (A mechanical agitator was used to break up the fibers). To this, add 15 ml of aqueous sol. of $Ba(OH)_2$ and NaOH (App. 35g $Ba(OH)_2.8H_2O$ and 10g Na OH(L). The agitation may be eliminated when extracting from dried meal. Use a 2 gram sample of dried meal.

Reflux the sample for 30 minutes using a water bath. Agitate the mixture occasionally during refluxing. Cool after finishing refluxing.

Filter through a buchner funnel using vaccum. Wash flask and fibers with 85% Acetone until all traces of yellow pigment are removed. Transfer filterate to a Separatory funnel. Wash flask to remove all color traces using 85% Acetone.

Add (50 ml) petroleum ether, agitate gently, allow phasic separation to occur. The product in the ether layer will be largely the carotenes, though Chlorophylls and Xanthophylls will also be present. Remove the Acetone layer, wash with pet. ether. The pet. ether layer is added to the first extraction. The Acetone layer is then discarded.

Add (30 ml) methyl Alc. to the ether solution. Chlorophylls and Xanthophylls are selectively absorbed by the alcohol and phasic separation is made. Wash the ether solution, making separations until the alcohol layer is colorless. Add a small amount of pet. ether to alcohol solution to absorb any carotene that may have passed into that solution. Add this to the ether solution.

Filter the ether solution into a 100 ml measuring flask. Wash filter paper carefully with pet. ether. Also separatory funnel. Make up solution to 100 ml.

Analyze the above solution using colorimeter. If Chlorophylls are present apply correction to readings obtained.

MOISTURE DETERMINATION

The moisture in the green feed, recycle, and product was determined by accurately weighing 5 gram samples of each, and then drying at 120 degrees centigrade until they came to constant weight.

Since the recycle rate was known and also the green feed rate, the moisture in the feed mixture could be determined.

For Example:

Green feed rate 1.38#/minute at 81.2% moisture

Recycle rate 9.85#/minute at 9.62% moisture

1.38 X 81.2% equals 1.12 pounds of water/min.

9.85 X 9.62% equals .948 pounds of water/min.

1.12 plus .948 equals 2.068#/min. total water entering

1.38 plus 9.85 equals 11.230#/min. total feed

2.068/11.23 X 100 equals 18.4% water in the entering feed mixture

DATA

RUN #1 May 19th

Green feed 28¼ # time 29 minutes

Recycle feed 16 #

Gas tank went empty during this run. Heat supplied to drier reduced. Time lost approximately 4 minutes while changing tank.

RUN #2

Green feed 44¼ # time 32 minutes

Recycle was continued from Run #1

Green feed rate 1.38#/min
Recycle rate 9.85#/min

Product 16¼ #

Recycle removed at end of run 13½ #

Power amps. 7 avg.
volts 440
P.F. 68

Temperatures

Entering bottom	entering top	leaving blower
1000 - 1300	900 - 1200	180 - 260

Propane used 3¼ #

Moisture

Green feed 81.2%

Recycle 9.62%

Product 7.72%

Recycle ratio 7.15 # per # green feed

No antioxidant was used in runs 1 and 2. Recycle was made up of old dry hay which had been ground in the mill.

RUN #3 May 26th

Green feed 25# time 20 minutes

Recycle 20#

Antioxidant - Publicker # 1

Carrier - soybean oil plus acetone

Moisture

product 11.1%

recycle 8.6%

RUN #4 May 26th

Green feed 25# time 21 minutes

Recycle 13#

Antioxidant - Publicker # 1

Carrier - Propylene glycol

Moisture

product 13%

recycle 8.6%

Runs 3 and 4 had recycle made up of old dry hay

RUN #5 June 1st

Green feed 89# time 78 minutes

Recycle 15#

Antioxidant - none

Samples taken after 50 and 89 #

Motor overheated after 89# had been run and stopped at this point.

Entering gas temperatures 900-1000 degrees F

Moisture Prod. #1 8.1% #2 7.5%
Recycle #2 9.5% #3 14.7%

Propane used 6 #

RUN #6 June 27th

Green feed 38½ # time 40 minutes

Recycle 8

Antioxidant - 2,5 di-tert-butylhydroquinone

Carrier - Soybean oil plus acetone

Product 9½#

Recycle removed 6 #

Moisture Product 7.54%

RUN #7 June 27th

Green feed 38½ # time 39 minutes

Recycle 8 #

Antioxidant - p- Isopropoxydiphenylamine

Carrier - Soybean oil plus acetone

Product 9 #

Recycle removed 6½ #

Moisture in Product 7.5%

Run #8 June 28th

Green feed 31# time 35 minutes

Recycle 9½#

Antioxidant - NN di-sec-butyl-p-phenylenediamine

Carrier - Soybean oil plus acetone

Product 7#

Recycle removed 9½#

Moisture in Product 7.02%

Run #9 June 28th

Green feed 30# time 32 minutes

Recycle 9#

Antioxidant - Publicker #1

Carrier - Soybean oil plus acetone

Product 9#

Recycle removed 8#

Temperatures of Runs 6, 7, 8, and 9 800 - 1100

Power 6-7 amps at 440 volts and P.F. .65

Run #10

Green feed 43½# time 50 minutes

Recycle 12½#

Antioxidant - none

Product 9#

Temp. of entering gases 1000 degrees F

Temp. of leaving gases 250 degrees F

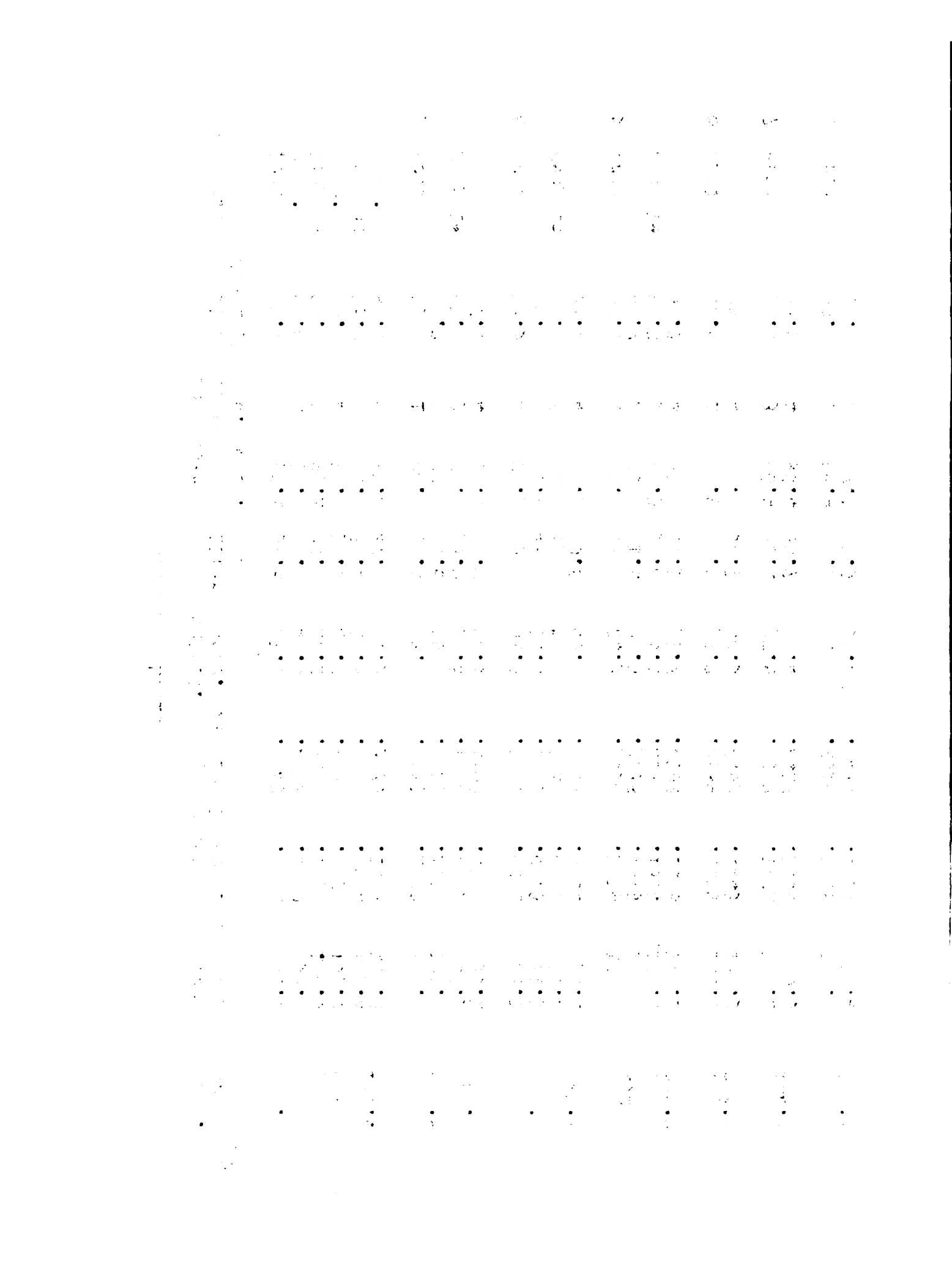
Power	Amps. 4-6 average 5 volts 440 P.F. .60 - .65	

Run #11

Green feed	90#	time 80 minutes
Recycle	15#	
Antioxidant	2,5 di-tert-butylhydroquinone	
Temperature	900 - 1200 entering gases 250 leaving gases	
Product	22#	moisture 9.8%
Recycle	14#	Propane used 6½#

CAROTENE ANALYSIS

Run	Sample	Photometer Filter 243 & 396	Flask No.	Corr.	Filter 554	Chlord. Corr.	Mg Carotene Per 100ml	Per gram	Micro gm/gm	Avg. Micrograms/gm
2	Fresh 4 gm.	97.7	1	95.1	39.8	41.9	.2243	.0561	56.1	55.6
		98.8	2	97.1	41.3	42.5	.2201	.0550	55.0	
	Recycle 2 gm.	96.6	3	93.1	39.9	42.8	.218	.1090	109.0	109
		96.3	4	92.6	39.6	42.8	.218	.1090	109.0	
	Product 2 gm.	95.7	5	91.5	28.2	30.8	.3104	.1552	155.2	161.4
		95.1	6	90.4	27.2	30.5	.3135	.1675	167.2	
3	Prod	93	1	86.9	37.5	43.2	.2153	.1077	107.7	104.6
		93.7	2	88	39.6	45	.2027	.1014	101.4	
	Recycle	97.0	3	93.9	55.0	58.6	.1346	.0673	67.3	61.2
		97.6	4	93.0	61.0	64.3	.1102	.0551	55.1	
4	Prod	97.3	1	94.5	49	51.9	.1661	.0831	83.1	82.2
		96.7	2	93.2	49	52.6	.1625	.0813	81.3	
	Recycle	92.5	3	86	55	64	.1115	.0558	55.8	56.0
		97.8	4	95.3	60.8	63.8	.1124	.0562	56.2	
5	Prod	95.2	1	90.6	22	24.3	.3838	.1919	192	192
		93.7	2	88	21.4	24.3	.3838	.1919	192	
	Recycle	97.8	3	95.3	34.4	36.1	.2672	.1334	133.4	126.6
		98.7	4	97	38.5	39.7	.2392	.1198	119.8	
6	Prod	98.6	1	96.9	36.5	37.7	.2539	.1269	126.9	125.8
		98	2	95.8	36.7	38.3	.2493	.1243	124.3	
7	Prod	98.6	3	96.9	36.4	37.6	.2547	.1274	127.4	124.2
		99.5	4	98.4	38.7	39.4	.2417	.1209	120.9	
8	Prod	98.6	1	96.9	36.8	38	.2516	.1258	125.8	124.6
		98.8	2	97.1	37.5	38.6	.2472	.1234	123.4	

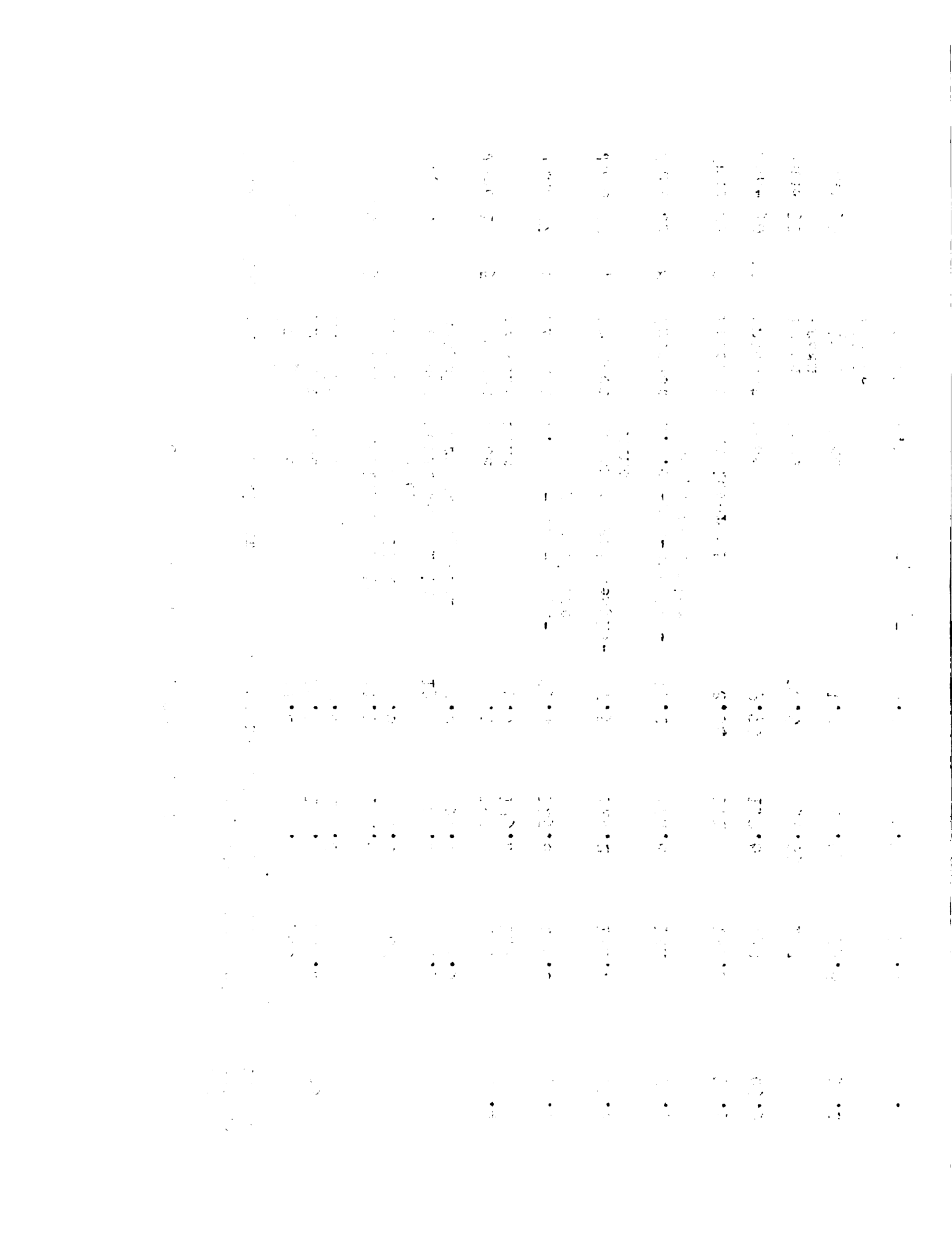


CAROTENE ANALYSIS

Run	Sample	Photometer Filter 243 & 396	Flask No.	Corr.	Filter 554	Chlord Corr.	Mg Caretene Per 100ml	Per gram	Micro gm/gm	Micrograms/gm
9	Prod	98.8	3	97.1	37.6	38.0	.2516	.1258	125.4	121
		98.6	4	96.9	39.4	40.6	.2333	.1166	116.6	
10	Prod	96.6	1	93.1	38.2	41.0	.2306	.1153	115.3	117.6
		98.6	2	96.9	38.5	39.7	.2396	.1198	119.8	
	Fresh green 4 gm	99	1	97.6	52	53.3	.1593	.0398	39.8	39.95
		98.8	2	97.1	51.8	53.4	.1602	.0401	40.1	
	Air Dry	99.5	3	98.6	51.3	52.1	.1651	.0826	82.6	82.55
		99.0	4	97.6	50.9	52.2	.1649	.0825	82.5	
11	Prod	96.6	5	93.1	33	35.4	.2719	.1359	135.9	135.9

CAROTENE ANALYSIS AND COMPARISON

Date	Run	Sample	Antioxidant	Moisture	Wet Basis Micrograms/ gm	Dry Basis Micrograms/ gm	% of Carotene Retained
May 19	2	Fresh green	None	81.4	55.6	306	
		Product	None	10.3	161.4	180.2	59
		Recycle	None	9.8	109.0	121	
May 26	3	Product	Publicker #1 in	11.1	104.6	118	
		Recycle	Soybean oil & Acetone	8.6	61.2	67	
May 26	4	Product	Publicker #1 in	13	82.2	94.5	
		Recycle	Propyleneglycol	8.6	56.0	61.3	
June 1	5	Product	None	8.1	192	209	68.4
		Recycle	None	9.5	133.4	147	
June 27	6	Product	2,5 Di-tert-Butyl-hydroquinone	75.4	125.8	136.0	72.8
June 27	7	Product	Isopropoxydiphenylamine	7.5	124.2	134.2	71.8
June 28	8	Product	N.N.di-sec-butyl-p-phenylenediamine	70.2	124.6	134	71.7
June 28	9	Product	Publicker #1	8.04	121	131.8	70.5
June 30	10	Product	None	9.76	117.6	130	69.5
June 30		Fresh green	None	78.6	39.95	187	
June 30		Air Dried 4 days	None	11.8	82.55	93.6	50.1
June 30	11	Product	2,5 Di-tert-Butyl-hydroquinone	9.8	135.9	150.6	80.4



SUMMARY OF DATA

RUN	FEED RATE #/min (green feed)	% of Caretene retained in Product
1	1.025	----
2	1.38	59
3	1.25	----
4	1.19	----
5	1.14	68.4
6	0.964	72.8
7	0.988	71.8
8	0.89	71.7
9	0.937	70.5
10	0.87	69.5
11	1.125	80.4
Air Dried (4 days)		50.1

CALCULATIONS

1. Weight of alfalfa

   measured

2. Length of run

   measured

3. Feed rate

   # feed/time = #/min.

4. Moisture

   $$\frac{\text{Grams of water in sample}}{\text{total wt. of sample}} \times 100 = \%\ \text{water}$$

5. Moisture in feed mixture

   explained under moisture determination

6. Power

   $$\text{Power} = \frac{EI \cos \theta\ (\text{time})}{1000} = \text{kilowatt-hrs}$$

   H.P. = kilowatts/.746

7. Hourly production on 10% moisture basis

   $$\frac{\#/\text{min of feed} \times 60 \times (1 - \text{moisture in green feed})}{1 - \text{Moisture in product}}$$

   Ex.

   $$\frac{1.38 \times 60 \times .2}{1 - .1} = 18.4 \text{ pounds dried meal/hr.}$$

8. H.P. required

   $EI \cos \theta / 746 = 440 \times 6 \times .65/746 = 2.3$

9. Power consumed

   H.P. x 746 / 1000 = 2.3 x 746 / 1000 = 1.714 KWH

CALCULATIONS

1. Weight of alfalfa

   measured

2. Length of run

   measured

3. Feed rate

   # feed/time = #/min.

4. Moisture

$$\frac{\text{Grams of water in sample}}{\text{total wt. of sample}} \times 100 = \% \text{ water}$$

5. Moisture in feed mixture

   explained under moisture determination

6. Power

$$\text{Power} = \frac{EI \cos \theta \text{ (time)}}{1000} = \text{kilowatt-hrs}$$

   H.P. = kilowatts/.746

7. Hourly production on 10% moisture basis

$$\frac{\#/\text{min of feed} \times 60 \times (1-\text{moisture in green feed})}{1-\text{Moisture in product}}$$

   Ex.

$$\frac{1.38 \times 60 \times .2}{1-.1} = 18.4 \text{ pounds dried meal/hr.}$$

8. H.P. required

$$EI \cos \theta \; / \; 746 = 440 \times 6 \times .65/746 = 2.3$$

9. Power consumed

   H.P. x 746 / 1000 = 2.3 x 746 / 1000 = 1.714 KWH

10. Fuel consumption

Fuel rate/Product rate = #fuel/#product

Calculations in the analysis for Carotene

Column (Sample)

measured weight

Column (filter 243 & 396)

read from meter on colorimeter

Column (flask number)

number on the sample flask

Column (Corr.)

chlorophyll correction taken from calibration tables for the reading from filters 243 & 396

Column (Chlore. Corr.)

$\frac{\text{Column (filter 554)}}{\text{Column (Corr.)}}$ = carotene reading corrected for chlorophyll

Column (Mg carotene/100ml)

taken from calibration charts comparing colorimeter readings with concentration of carotene

Column (Mg carotene/gm)

$\frac{\text{Column (Mg carotene/100ml)}}{\text{sample weight in grams}}$ = concentration of carotene

Column (Micro gm/gm)

Column (Mg carotene/gm) x 1000 = micro gms/gm

Column Avg.

Average concentration of two samples of the same product (weights are on wet basis)

Concentration on dry basis

Column (Avg)/1-moisture content of sample = concentration of carotene per gm. on dry basis

DISCUSSION

RUNS 1 and 2

Runs 1 and 2 were run at maximum capacity. Highest temperature was maintained and feed rate highest which would not overload motor and mill. It was noticed that the limiting factor of overload on mill also controlled the temperature which it was possible to use. When the temperature of the entering gases went above 1300 it was not possible to feed enough green alfalfa to the mill to keep the temperature low enough to prevent igniting the dry alfalfa. If more green alfalfa was fed, the mill became clogged and more of the gases were pulled in through underneath the mill, increasing the temperature in the elutriator to a point where the dry meal was ignited. If more recycle had been fed with the green feed, the motor would have become overloaded. At high temperatures the bearings became overheated so that the lubricant flowed away from the bearings. For long continuous runs these bearings should be cooled in some manner.

RUNS 3 and 4

Old dry hay was used as recycle material. The shortness of the run and large amount of recycle were responsible for the low carotene content as considerable amount of the old hay recycle passed over into the product. The purpose of these runs was to test the effect of different carriers on

the retention of carotene while still using the same antioxidant. From the results, it appears that soybean oil plus acetone was better as a carrier than propylene glycol. As a result of this run, soybean oil plus acetone was used for all other antioxidant runs.

RUN 5

In this run 89# of green feed was used. Samples were taken after 50 and 89 pounds of green alfalfa had been fed to mill. The purpose of this run was to obtain a run long enough so that the recycle material would not enter into the carotene analysis. It was found that the samples after 50# and 89# agreed very closely, so it was reasonable to conclude that the recycle introduced at the beginning of the run had no more effect on the carotene content in the product after 50# of green feed had been introduced.

RUNS 6 - 9

These runs were made considerably later in the season than the first five runs. As a result, the alfalfa was quite mature and the stalks were heavy, making up a greater portion of the weight than earlier in the season. It was found that the carotene in the green alfalfa was much lower than at the earlier date; therefore it is difficult to compare the carotene content with the early runs. Comparison was based on the % of total carotene in the green alfalfa which was retained after drying.

It was noted that antioxidants increased the % of carotene retained in runs 6 to 9. There was not a great deal of difference in the effect of the various antioxidants; 2,5 di-tert-butylhydroquinone appeared to be the best. However, it is suggested that the equipment be improved to permit longer continuous runs, and that the tests be carried out using long runs.

RUN 10

This run was made as a control for runs 6 to 9. Since the runs using antioxidants had been run later when the carotene content of the green feed was low, a new basis for comparison was needed. However, based on the % of carotene retained, runs 10 and 5 agreed quite well.

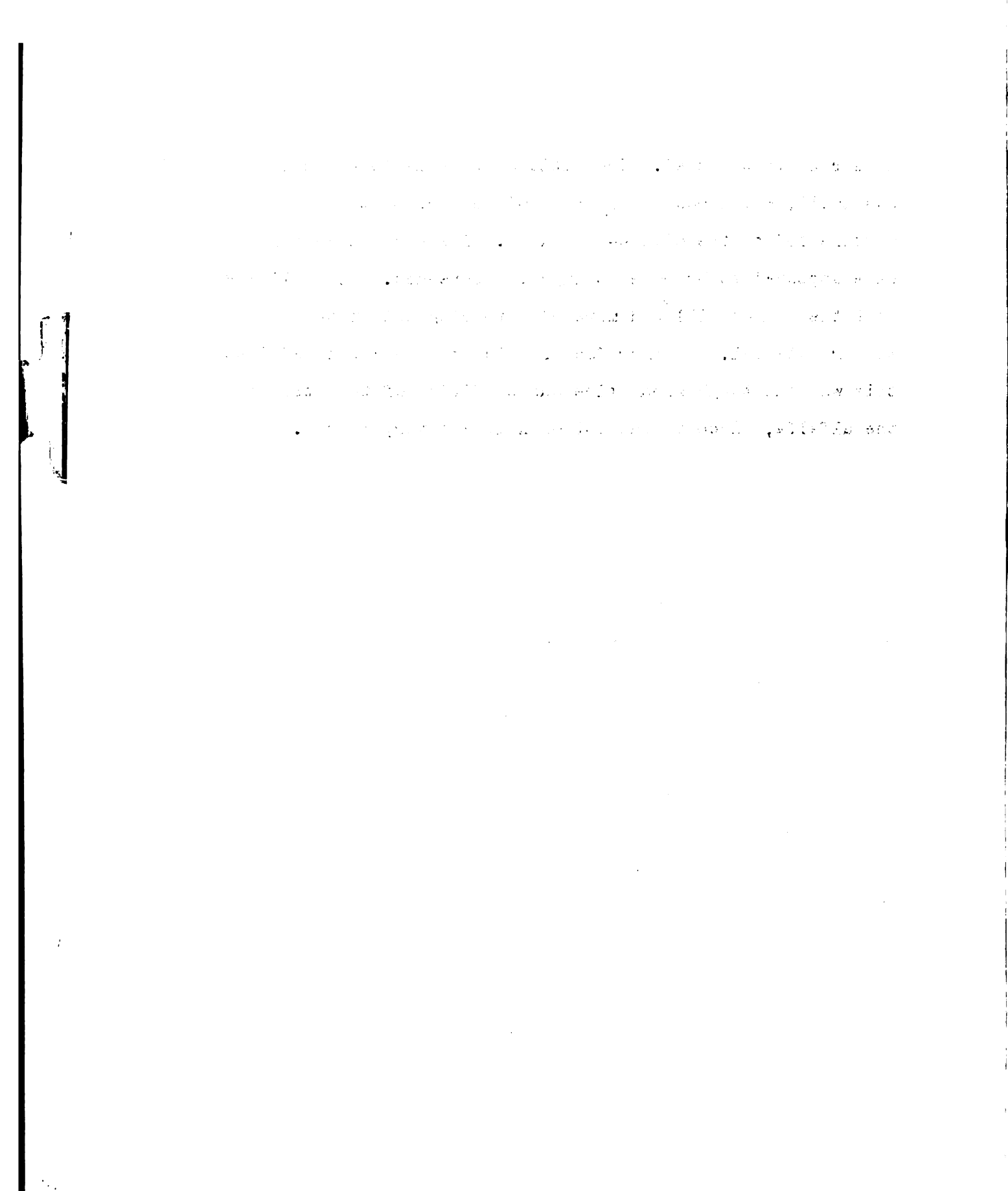
RUN 11

This was a long run of 90# using 2,5 di-tert-butylhydroquinone for the antioxidant. It was found that 80% of the carotene was retained in the sample taken at the end of this run.

The lower feed rate in the later runs was used in order not to overload the mill and cause stoppage during the runs. The temperature was lowered in order not to overheat the bearings on the mill.

When the amount of recycle was small, as in runs 6 and 7, the texture of the product was different than when

more recycle was used. The ratio of recycle to green feed was small, which means that the moisture content of the mixture fed to the mill was greater. The product in this case appeared to be more stringy and shredded. It is likely that the hammer mill had more of a tearing action on the wetter material. Another factor which may have entered into this was the tough woody fiberous condition of the stems of the alfalfa, since it was cut when it was very mature.



CONCLUSION

The maximum capacity of the mill appeared to be about 1.4 #/minute of green alfalfa containing 81% moisture. On an hourly basis this would be 84#/hr of green feed, which would result in an hourly production of 17.75# of dried meal containing 10% moisture.

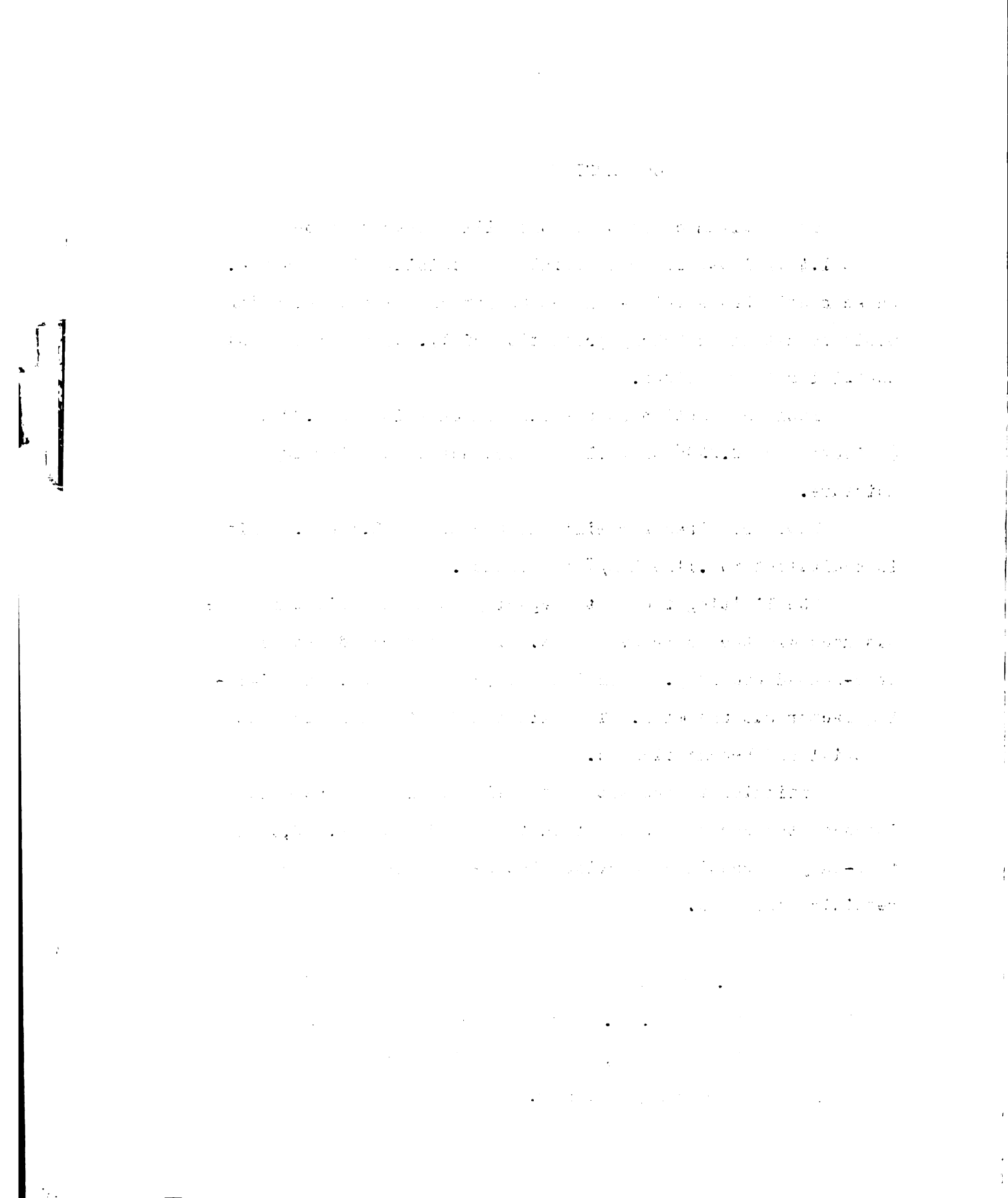
Fuel consumption at the maximum capacity was .0734 #/minute or 0.248# of fuel/# of product containing 10% moisture.

Power required for mill and blower was 2.1 kwh. This is equivalent to .1183 KWH/# of product.

The limiting factor to capacity when sufficient recycle was used was the power available. The motor would become over-heated and stop. When less recycle was used, the limiting factor was the mill. The mill would not handle the wet material and became clogged.

Antioxidants present in the alfalfa fed to the mill improved the carotene content in the dried product. 2,5 di-tert-butylhydroquinone provided the best protection for retaining carotene.

The rate of recycle at maximum capacity was 7# of recycle to 1# of green feed. This is equivalent to a moisture content in the entering feed mixture of 18.6% . A ratio of 6 : 1 would result in a moisture content of about 22%, which could still be handled by the mill easily without clogging the screen.



BIBLIOGRAPHY

1. Thompson, C. Ray - Industrial Engineering Chemistry
May 1950, page 923

2. Kennett, Wilbur - Thesis 1950, Michigan State College

3. Tauber, Henry - Journal of American Chemical Society
1941, page 2251

4. Strain, H. H. - Journal of American Chemical Society
1941, page 3542

5. Silker, R. E., W. G. Schrenck, H. H. King, Industrial
and Engineering Chemistry
1941, page 831

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