Bulletin 129. May 1908

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

Extraction of Beeswax

BY

F. C. ALFORD

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1908

The Agricultural Experiment Station.

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE

		TERMS EXPIRE
HON. JAMES L. CHATFIELD	Gypsum	1909
HON. B. U. DYE	Rocky Ford	1909
HON. B. F. ROCKAFELLOW, *President*	Canon City	1911
HON. E. H. GRUBB	Carbondale	1911
HON. R. W. CORWIN	Pueblo	1913
HON. A. A. EDWARDS	Fort Collins	1913
HON. F. E. BROOKS	Colorado Springs	1915
HON. J. L. BRUSH	Greeley	1915
GOVERNOR HENRY A. BUCHTEL, PRESIDENT BARTON O. AYLESWORTH,	*ex-officio.*	

A. M. HAWLEY, SECRETARY — CHAS. SHELDON, TREASURER

EXECUTIVE COMMITTEE IN CHARGE

B. F. ROCKAFELLOW, *Chairman.*

A. A. EDWARDS. — B. U. DYE.

STATION STAFF

L. G. CARPENTER, M. S., *Director* ..... IRRIGATION ENGINEER
C. P. GILLETTE, M. S. ..... ENTOMOLOGIST
W. P. HEADDEN, A. M., PH. D ..... CHEMIST
WENDELL PADDOCK, M. S. ..... HORTICULTURIST
W. L. CARLYLE, M. S. ..... AGRICULTURIST
G. H. GLOVER, M. S., D.V. M. ..... VETERINARIAN
W. H. OLIN, M. S., ... AGRONOMIST
R. E. TRIMBLE, B. S. ..... ASSISTANT IRRIGATION ENGINEER
F. C. ALFORD, M. S. ..... ASSISTANT CHEMIST
EARL DOUGLASS, M. S. ..... ASSISTANT CHEMIST
S. ARTHUR JOHNSON, M. S. ..... ASSISTANT ENTOMOLOGIST
B. O. LONGYEAR, B. S. ..... ASSISTANT HORTICULTURIST
E. B. HOUSE, M. S ..... ASSISTANT IRRIGATION ENGINEER
F. KNORR, B. S. ..... ASSISTANT AGRONOMIST
W. G. SACKETT, B. S. ..... BACTERIOLOGIST
P. K. BLINN, B. S. ..... FIELD AGENT, ARKANSAS VALLEY, ROCKY FORD
E. R. BENNETT, B. S. ..... POTATO INVESTIGATIONS
MIRIAM A PALMER ..... ARTIST
L. C. BRAGG ..... ASSISTANT IN ENTOMOLOGY
STATE FRUIT INVESTIGATIONS:
O. B. WHIPPLE, B. S., Grand Junction ..... FIELD HORTICULTURIST
GEO. P. WELDON, Delta ..... FIELD ENTOMOLOGIST

OFFICERS

PRESIDENT BARTON O. AYLESWORTH, A. M., LL. D.

L. G. CARPENTER, M. S. ..... DIRECTOR
A. M. HAWLEY ..... SECRETARY
MARGARET MURRAY ..... CLERK

EXTRACTION OF BEESWAX

BY F. C. ALFORD

The increasing interest in apiculture in many sections of the State, and the frequent inquiries relative to the best method of extracting the wax, justify the preparation of this bulletin.

The combs used for the extraction of wax are usually old brood combs. These, of course, contain a large amount of foreign matter which renders the complete extraction of the wax very difficult, and results in forming a residue, known as slumgum.

Some of the methods in vogue at present have been practiced for a long time, others are of comparatively recent origin. Though I have sought for data, definitely established by experiments, regarding the relative efficiency of the different methods, I have been unable to find such, and have therefore attempted to establish the efficiency of some of the methods by experiments.

The classes of extractors experimented with include the solar extractors, those using steam, and those employing pressure under water at a temperature sufficiently high to melt the wax. We have experimented with the latter, using water alone, and also with the addition of sulphuric acid.

All experiments in extracting the wax were made with portions of one large lot of comb, and under comparable conditions. In those cases in which specific instructions were sent out by the manufacturers of the extractor, they were followed faithfully.

The study of this subject was extended to include the refining and bleaching of the wax, and also to include an indicator to find out something definite relative to the character and wax content of slumgum.

In all of this work we have been mindful of the suggestions and theories advanced by apiculturists during recent years, which was, of course, necessary in order to bring our work abreast with that of the Bee-keepers' Associations and individuals. I have profited by the suggestions of some of the prominent refiners of and dealers in beeswax who kindly answered my inquiries addressed to them, but in general I have found information regarding the extraction of beeswax very scarce, at least it is very difficult to obtain.

The General Properties of Beeswax. Beeswax, when obtained from clean, fresh comb, is a tough, compact solid, having a yellowish or brownish color, a fine granular structure and a very little luster. Its taste is faint and balsamic, but the odor is honey-like and characteristic. Beeswax does not feel greasy to the touch. It loses is color, bleaches, when exposed to the action of moisture and light, some varieties with

great difficulty. The presence of a small amount of fatty matter seems to facilitate the process. The melting point of beeswax varies with different samples, due to the fact that the proportion of its constituents may vary. The melting point is higher in old than in fresh wax, i. e., the melting point increases a little as the wax ages. Yellow wax melts between 61° and 63° C. (141.8° and 145.8° F.) Its specific gravity varies from 0.96 to 0.97 at 4° C.

The average composition of beeswax is, cerotic acid, soluble in alcohol, 14.4%; myricin, insoluble in alcohol, 85.09%. There are, further, other compounds present, two hydrocarbons having been definitely recognized. The composition of genuine beeswax is approximately constant, and is not changed by natural bleaching, but chemical bleaching may increase the relative percentage of acid to 17 or 18%.

Comb Used. As the comb varied considerably, care was taken to get a fair sample for each experiment. The comb used was mostly old black comb which had been used as brood comb and was furnished by some of the beekeepers of the state and the Entomologist of the Station. The comb was sorted into three different grades; that designated as comb number one was white comb which had not been used for breeding purposes. Number two comb was light brown, which had been used as a brood comb. It was darker than number one but not as dark as number three. Comb number three was a real dark comb and had been used for breeding purposes for a long time. Almost all of the experiments were conducted with combs numbers two and three, as almost all methods are very efficient with comb like number one.

Samples. Realizing that a little difference in the samples taken for the experiments would make a greater difference in the final result, we were very careful in the sampling of the material for the experiments. The comb was cut into pieces about an inch square and placed in a pile. The pile was stirred until well mixed, divided into quarters and the two opposite quarters placed in a pile. This pile was stirred and sampled as before. This process was continued until a sample of the proper weight was obtained.

SOLAR EXTRACTORS.

Two kinds of solar extractors were used, known as numbers one and two. Number one consisted of a wooden box thirty-two inches long, eighteen inches wide, and four inches deep. At the lower end a small box is placed to hold the pan which catches the wax. Twenty-four inches from the top there is a screen to hold back the comb. The upper portion of the box is lined with tin and the waste wax and brood comb are placed in this part of the box. The box is covered with a pane of glass held in a frame which fits the upper edge of the box. The heat from the sun melts the wax and it runs down, is strained by the screen, and is collected in a pan at the lower portion of the tin.

Number two extractor consists of a wooden box sixteen inches broad, seven inches deep and thirty inches long and has legs near one end so that it can be raised up at an angle toward the sun. The interior

is fitted with a concave tin lining to hold the pieces of comb, separated by a wire cloth straining screen from the wax pan, at the lower end of the box.

These two extractors were used because it was thought they represented, as nearly as possible, the average of the solar extractors used in this country. Some beekeepers have solar extractors which are much larger than either of these, but it is doubtful if they remove a greater percentage of the wax from the comb.

The experiments conducted with the solar extractors were made, as nearly as possible, under the same conditions. They were made on the same day and within a few feet of each other, on the south side of the Chemical Laboratory, so as to get the same outside temperature.

Number one held about twice as much comb as number two. On this account, it was necessary to fill number two extractor twice while number one was filled once. The first experiments were made to determine the comparative efficiency of these two solar extractors. For number one comb, extractor number two produced on the average about one per cent. more wax; for number two comb, about two per cent. more, and for number three comb, about one per cent. more than extractor number one.

The temperature of the extractor varied so much on different days that it was very hard to tell which extractor had the higher temperature. One day number two would have a higher temperature and the next day number one would. Taking an average of all the experiments where the temperatures were taken I find extractor number two exceeded extractor number one by about 0.4°C.

Solar Extractor with Lamp. It is the practice of some beekeepers to operate a lamp, stove or furnace in connection with the solar extractor. The extractors were inclined at an angle of about thirty degrees and an inclosure built back of them, to keep the wind from blowing the lamp. A lamp was placed inside the inclosure and a hole made in the bottom of the extractor so that the flame would strike against the tin lining of the extractors.

The addition of the lamp helped the extractor to heat up in the morning, to remain warm in the evening, and on a cloudy day, to keep the extractor warm when the sun was under a cloud.

By the use of the lamp the efficiency of the extractor was increased on an average about one per cent. The best results were obtained by having the heat from the lamp strike directly under the wire screen. Often on a cloudy day the wax will run down as far as the screen and then cool. By having the heat from the lamp warm the screen and the surrounding metal the wax is kept from cooling and runs down into the pan.

Double Glass. It was thought that the addition of an extra pane of glass might increase the yield. In order to try this an extra pane of glass was placed on extractor number one with one-half inch space between the panes. It was found that the use of the second pane increased the inside temperature on an average about 9.4° C. (17° F.) It was

observed that the extractor with the double glass was slower in becoming heated in the morning and held the heat longer in the evening. The efficiency of the extractor was increased, on an average, about seven per cent. for number two comb, and two per cent. for number three comb. Number one comb was not tested.

Double Glass and Lamp. As it was shown by experiments that the use of a lamp, and an extra pane of glass increased the efficiency it was thought that a combination of the two might increase it still more. This was tried and the results showed but a slight increase over either one alone and did not come up to expectations. The increase was about 0.7 per cent.

Bleaching. It was noticed that in rendering light colored wax by means of the solar extractor the wax was bleached. An attempt was made to determine the bleaching effect of the sunlight by exposing dark wax in the solar extractor for four days. The wax was exposed for that length of time because it was thought that it would not remain in the extractor longer than that during the ordinary process of extraction. Some dark wax which had been obtained from the Ferris steam extractor was placed in solar extractor number one and melted for a day. A sample of this wax was taken and the remainder remelted. This was continued for four days and samples were taken at the end of each day. At the end of the fourth day the samples were compared and it was impossible to note any change in the color of the wax.

Some dark wax which had been boiled with sulphuric acid was placed in solar extractor number two and melted. It was sampled and remelted the same as in the preceding experiment. It was impossible to notice any difference in the shade or color of the wax.

Slumgum. In order to see if the solar extractor could remove wax which the steam extractor was unable to remove, some slumgum from the Swiss extractor was put in solar extractor number two and heated for four days. The weather was very warm and at the end of the fourth day there was not a trace of wax to be seen in the extractor.

Honey. A number of experiments were made to see if the solar extractor could be used to remove honey from the comb. In the experiments conducted with the dark comb in warm weather, the honey obtained was dark and thick, had a scorched taste and could not be used for anything except feeding purposes. In the other experiments with light colored comb and with moderately bright sun the honey was light colored and of good quality.

Soaking Comb in Water. Some beekeepers make a practice of soaking the comb in water before putting it in the solar extractor, supposing that the soaking loosens the cocoons and dirt in the comb. Some number two comb was soaked in water for six days and put in solar extractor number one. Some comb which had not been soaked was used as a check, and the soaked comb showed an average increase of about one per cent. over the unsoaked.

Comb Soaked in Dilute Sulphuric Acid. It was thought that the soaking of the comb in dilute sulphuric acid might loosen the dirt and

cocoons and leave them in a free condition. Some number two comb was soaked for three days in a solution of five per cent. sulphuric acid, washed to remove the acid and treated in solar extractor number one for three days. Some comb which had not been soaked was used as a check, and the comb treated with acid gave on an average about five per cent. more wax than that not treated. Care had to be taken to wash all of the acid out of the comb before it was put in the extractor on account of the action of the acid on the metal linings of the extractor.

STEAM EXTRACTORS.

In determining the efficiency of the steam extractors three kinds were used, the Ferris, the Root-German, and the Swiss. The Ferris extractor was loaned to the department by Mr. M. A. Gill of Longmont, Colorado, and the Root was loaned by Mr. R. C. Aikin of Loveland, Colorado. The Swiss was obtained from the Station Entomologist.

The Root-German Extractor. This extractor was made by the A. I. Root Co., Medina, Ohio, and consisted of a small sheet iron tank or can with a false bottom. On an iron frame above the false bottom rests a wire basket. Pressure is applied by means of a screw which runs through the cover of the machine. Water is placed in the bottom and the machine placed on a stove. The steam, as it generates, rises through a hole in the middle of the false bottom, which is covered by a deflector. The comb, not too much, is placed in a burlap bag and the bag is placed in a metal basket which is put into the extractor. When the comb becomes thoroughly melted pressure is applied by means of the screw, increasing at intervals and not applied all at once. After most of the wax has been removed it is a good thing to remove the pressure, stir the slumgum and press again. With old comb it is best to stir and press at least two or three times. This extractor worked in a very satisfactory manner and the results show the efficiency of the Root extractor to be greater than that of any of the other steam or solar extractors.

The Ferris Steam Wax Extractor. This extractor was invented by Mr. C. C. Ferris of Richfield Springs, New York, and was the first extractor put on the market which used pressure in connection with steam as a means of extracting beeswax. The extractor consists of a galvanized iron tank in which are suspended two extra heavy galvanized wire-cloth baskets. Comb is placed in the baskets, water is put in the lower portion of the machine and the whole is placed on the stove. The steam as generated, passes upward into the baskets and melts the wax which runs down the inclined bottom and out the spout into a pan containing water. After part of the wax has melted pressure is applied in the basket by means of a screw and the wax is forced out of the comb while it is kept hot by steam. The comb is then stirred, heated and pressed again.

The Ferris extractor worked very well on number one comb, but it did not give good results with either comb numbers two or three. The machine was not made strong enough so that sufficient pressure could be applied to force all of the wax out of the comb. The screws for applying the pressure were too small and the method of fastening them not

very secure. The results show that on an average the efficiency of the Ferris extractor is about one per cent. below the Root extractor for number two comb and about twelve per cent. below for comb number three.

The Swiss Steam Wax Extractor. This extractor is made in two sections. The lower one is an ordinary can and contains water. The upper section has a bottom in the shape of an inverted funnel and rests on the lower one. Inside the upper section is placed a basket made of galvanized wire-cloth. The wax is placed in the basket and the machine placed on the stove. Steam is generated in the bottom, passes up through the hole in the center of the funnel shaped bottom of the upper section and comes in contact with the comb in the basket. The wax in the comb melts and runs down and out of a spout into a pan containing water. The Swiss extractor was used without pressure and the result shows an increase in efficiency caused by the use of pressure in wax extraction. The Swiss extractor can be used in connection with a press by putting the comb in a sack and transferring it to the press, but this method gives the wax a chance to cool and is not as efficient as some of the others.

Remelting Test. The results given above are for the wax as it comes out of the extractor. It was thought that it might be well to determine the amount of dirt in the different samples of wax. The wax used was that obtained in some of the preceding experiments with the Ferris, Swiss and solar extractors.

The wax obtained from each extractor was broken into small pieces, the sample thoroughly mixed, and a separate portion weighed and remelted in each of the four extractors. The wax from the steam extractor was allowed to drop from the spout into a dish of water on a water bath. The heat of the water in the water bath kept the wax melted and the dirt settled to the bottom. Owing to the lateness of the season the wax in the pans of the solar extractors did not remain melted. To have the conditions as near as possible the same as in the steam extraction, the wax from the solar extractors was put in a dish on the water bath, heated and the dirt allowed to settle. In both cases the dirt which had settled to the bottom of the cake was trimmed off and remelted over a water bath. This process was continued until all of the dirt was removed. The percentage of clean wax obtained was, for the solar extractor number one, 94.66, the solar number two, 96.19; the Ferris, 96.31, and the Swiss, 94.38.

Pressing Under Water. The comb, with some water, was put in a tub on the stove and the wax allowed to melt, but not to boil. A can was placed under a press and a slatted follower placed in the bottom of the can. Above this was placed a burlap bag and the hot water, melted wax and comb were poured into the bag, the top of the bag folded over, a slatted follower placed on top and pressure applied by means of a screw. After some of the wax had been forced out, the water and wax were drawn off, the pressure relieved, the slumgum stirred, hot water added and pressure applied again. The can, which fits under the press, has two holes which are stopped by corks. One is at the bottom and the

other near the top. By pulling the cork out of the upper hole the wax which has risen to the top can be drawn off and by using the lower hole all of the wax and water can be removed. The whole apparatus must be kept as warm as possible. An inside can with holes in the sides was tried but did not give good results.

In the following, average results are given because in the first two trials some of the wax adhered to the bag and follower. This method proved very efficient, giving about one per cent. more wax than the Root extractor with number two comb and about six per cent. more with number three comb. The main points in this method were received from Mr. Gill of Longmont, Colo., whose method is somewhat similar except that in his case the wax was dipped from a boiler and placed in the press.

Sulphuric Acid and Pressure Under Water. It was thought that the addition of acid to the water in the experiment might increase the efficiency of the method. The comb was heated in a porcelain lined tub with a solution of five per cent. commercial sulphuric acid. When the wax had melted it was poured into the sack in the press and pressure applied quickly in order not to have the acid in contact with the metal any longer than necessary. The wax and water were drawn off, boiling water added, the slumgum stirred and pressure applied again. This water was drawn off and put with the rest. As this was an experiment to determine the efficiency of the press a tin can was used, but in practical work it would be necessary to have everything acid proof, as hot acid even when diluted, is very destructive to most substances. The can could be made of wood or porcelain lined ware. The latter would probably be the better.

This method was easy to manipulate and rapid and was the most efficient of all the methods used. This method gave about seven per cent. more wax for number two comb and seven per cent. more for number three comb than did the Root extractor.

Comparison of Different Methods. The following table shows the efficiency of all methods with combs number two and three and are average results. Number one comb was not used in all the extractors because most methods give good results with new clean comb:

	Result in Percent.	
	Comb. No. 2	Comb. No. 3
Solar extractor, single glass	31.02	10.24
Solar extractor, double glass	38.27	12.79
Swiss steam extractor	48.59	21.30
Ferris steam extractor	58.02	25.60
Root steam extractor	59.43	37.83
Pressure under water	60.55	44.42
Pressure under water with sulphuric acid	67.02	45.19

COLOR OF THE WAX.

The wax produced by the Root, Ferris or Swiss extractor did not have a good color and would have had to be refined before it could be used. The wax from the solar extractors was always a better color than

that from the steam extractors. The wax formed by pressure under water was nearly as good in color as the wax from the solar extractors. The wax obtained by pressure under water containing five per cent. of sulphuric acid was very good in color, in fact, almost as good (with combs number two and three) as most of the wax obtained from the solar extractors.

I believe the color of the wax from the steam extractors to be due to the presence of iron, owing to the metal in the extractor coming in contact with the steam. The wax from the Ferris and Root extractors was tested and showed the presence of small quantities of iron; enough perhaps to account for the color. The wax from the solar extractors did not show the presence of any iron.

Bleaching Wax. In a search for a method for bleaching beeswax I found many compounds which would effectually bleach the wax, but most of them either destroyed the wax or were in themselves poisonous. Chlorine, which is a great bleaching agent, cannot be used on account of its forming, according to Allen, chlorination substitution—products which may give rise to hydrochloric acid. Beeswax can be volatilized almost without change in a vacuum but when distilled under ordinary pressure it yields a variety of products. Therefore this method cannot be used in purifying beeswax.

The principal use of beeswax is in the manufacture of comb foundation which is given to the bees to act as a foundation on which to build their comb. In order to get nice, white honey the foundation must be light colored. The following experiments were made to determine the best method for cleaning and bleaching wax.

Acids Used in Bleaching. The beeswax on which this experiment was made was a sample of wax that had been rendered from dark colored comb. It was heated in water so as to get a uniform cake, which was cut into eight equal pieces and one piece taken for each test.

Piece number one was heated with 2 cc. of sulfuric acid and 200 cc. of water. Piece number two was heated with 2 cc. of hydrochloric acid and 200 cc. of water. Piece number three was heated with 2 cc. of nitric acid and 200 cc. of water. Piece number four was heated with 200 cc. of water. Piece number five was heated with 200 cc. of water and 2 cc. of a solution containing 60 cc. of sulfuric acid and 63 grams of potassium bichromate to 1000 cc. of water. Piece number six was heated with 200 cc. of water and 5 grams of sodium chloride or common salt. Piece number seven was heated with 100 cc. of the solution of sulfuric acid and potassium bichromate which was used with number five, mixed with 200 cc. of water. They were all cooled in the air and stood over water while cooling. Number one gave the best results and the wax was lighter colored than any of the others. Numbers two, three, five and six did not show much improvement over number four which was used as a blank for comparison. Number seven gave a very dark green wax.

This would go to show that as far as bleaching and removing the coloring matter, the sulphuric acid gives the best results of the materials used.

Sulphuric Acid and Hydrogen Peroxide. For this experiment a sample of dark wax which had been obtained from brood comb was used.

It was melted in hot water, formed into a cake, the cake cut in eight equal pieces and the pieces treated in the following manner:

Piece number one was heated with 100 cc. of water.

Piece number two was heated with 100 cc. of water and 2 cc. of sulfuric acid. Piece number three was heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 2 cc. of sulfuric acid. Piece number four was heated with 100 cc. of water, 10 cc. of hydrogen peroxide and 2 cc. of sulfuric acid. Piece number five was heated with 100 cc. of water, 15 cc. hydrogen peroxide and 2 cc. of sulfuric acid. Piece number six was heated with 100 cc. of water, 20 cc. of hydrogen peroxide and 2 cc. of sulfuric acid. Piece number seven was heated with 100 cc. of water, 25 cc. of hydrogen peroxide and 2 cc. of sulfuric acid. Piece number eight was heated with 100 cc. of water and 5 grams of oxalic acid. Piece number three, heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 2 cc of sulphuric acid, was much better than any of the others. Hydrogen peroxide was tested for and found in the water in which the wax had been melted. Excessive boiling with water seemed to injure the grain of the wax, but the heating with water and sulfuric acid and with water, sulfuric acid and hydrogen peroxide did not seem to injure the grain. Piece number eight showed only a slight improvement over the original sample.

Remelting with Sulphuric Acid and Hydrogen Peroxide. One-half of piece number three of the last experiment was remelted in 100 cc. of water, 2 cc. of sulfuric acid and 5 cc. of hydrogen peroxide. The color of the wax was very much lighter than before being remelted in 100 cc. of water, 5 cc. of hydrogen peroxide and 5 cc. of sulfuric acid. The wax was pressed out of the cloth and was very much improved. It had a golden yellow color and a good grain.

Increasing the Amount of Sulfuric Acid. The wax used in this experiment was dark and was obtained by rendering old combs. It was remelted and divided into eight equal parts. Number one was heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 2 cc. of sulfuric acid. Number two was heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 5 cc, of sulfuric acid. Number three was heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 10 cc. of sulfuric acid. Number four was heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 15 cc. of sulfuric acid. Number five was heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 20 cc. of sulfuric acid. Number six was the same as number five except that it was heated with 25 cc. of sulfuric acid. Number seven was inclosed in a canton flannel bag, heated with 100 cc. of water, 5 cc. of hydrogen peroxide and 2 cc. of sulfuric acid, and the wax squeezed out of the bag. Number eight was heated with 100 cc. of water. Number two gave better results than any of the others with the exception of number seven, which gave a very nice yellow wax.

Refining with Alcohol. The wax taken for this experiment was obtained by rendering old brood combs and was dark. It was remelted and divided into eight pieces. Number one was heated on the water bath with 100 cc. of barrel alcohol. Number two was heated on the water bath with 50 cc. of alcohol and 50 cc. of water. Number three was heated in the same manner as number two with 25 cc. of alcohol and 75 cc. of water. Number four, one-fourth of number one, was heated in water. In number one the wax dissolved and on cooling cerotic acid separated from the alcohol. In numbers two and three there did not seem to be any cerotic acid dissolved in the liquids. Number one gave a soft waxy substance, probably myricine. Number four gave a compact substance. Number five was as good in appearance and texture as any of the others. I could not see any improvement in the color of the wax caused by the treatment with alcohol.

The use of Cloth in Refining Wax. The wax used for this experiment was very dark and was divided into four equal parts. Piece number one

was inclosed in a piece of fine canton flannel cloth and heated in water which contained five per cent of sulfuric acid and five per cent of hydrogen peroxide. Number two was inclosed in a piece of fine canton flannel and heated in a solution of five per cent sulfuric acid. Number three was inclosed in a piece of coarse linen cloth and heated in a solution containing five per cent sulfuric acid and five per cent hydrogen peroxide. Number four was inclosed in a piece of fine canton flannel and heated in water. Number one gave the best results. The wax had a good color and a good grain. Number two was next to the best. Number three was not as good as either number one or number two. Number four was used as a check. All showed improvement over number four.

One-half of number one was placed in a canton flannel cloth and heated with a solution containing five per cent sulfuric acid and five per cent hydrogen. One-half of this last sample was placed in a canton flannel cloth and heated twenty minutes with a solution containing two per cent sulfuric acid and five per cent hydrogen peroxide. Three-fourths of the last sample was placed in a canton flannel cloth and heated with a solution containing five per cent hydrogen peroxide and two per cent sulfuric acid. The last sample was remelted in the same manner and the color could not be improved. The last two heatings did not seem to improve the color of the wax. The one before them, number two, gave the best colored wax and the wax had a good grain.

EXAMINATION OF THE SLUMGUM.

As stated under the properties of wax, the wax contains on an average of about 14.4% cerotic acid. There are two ways known for the determination of pure wax in impure beeswax. They both depend on the amount of cerotic acid in the wax which can be saponified in the presence of wood alcohol. Neither method is very satisfactory for dark colored wax. The amount of cerotic acid in the slumgum might be determined by one of these methods and the amount of wax in the slumgum estimated.

All of the slumgums gave cerotic acid and therefore contain some wax. I was unable to devise any method or modification of methods to determine the amount of cerotic acid in the slumgum. In the presence of so much coloring matter the indicators did not give good results.

Boiling with wood alcohol and decanting off the hot solution and titrating was tried, but was unsatisfactory. It was found that after boiling ten grams of slumgum with twelve portions of wood alcohol of 50 cc. each there still remained cerotic acid in the residue. The addition of hydrogen peroxide to the alcohol and slumgum did not cause an improvement. A red coloration was formed which covered the end reaction of the indicator.

SUMMARY.

In summing up the facts given in the preceding experiments, I draw the following conclusions:

In some ways the solar extractor is a good extractor for the beekeeper to have. It is convenient and requires very little attention. The solar extractor does not remove as much wax from the comb as the steam extractor. The residue, or slumgum, from the solar extractor may be worked over in the steam extractor and some wax obtained. The solar extractor can remove honey from the comb, but with ordinary comb and warm weather the honey is not of a very good quality.

The heat of the sun seems to bleach some kinds of wax, besides extracting it from the comb. In other cases it is difficult to notice any bleaching in wax which is exposed to the sun.

The steam wax extractor removes more dirt than the solar extractor. The steam extractor will remove honey from the comb, but the honey is usually very dark. In efficiency the steam extractor has an advantage of from ten to twenty per cent over the solar extractor.

In efficiency the solar wax extractor number two has a slight advantage over solar extractor number one, about one per cent for number one comb, for number two comb two per cent, and for number three comb about one per cent.

The addition of an extra pane of glass to the solar extractor raised the inside temperature on an average of 17 degrees F. The efficiency of the extractor was increased on an average about seven per cent. for number two comb and two per cent for number three comb.

The addition of a lamp to the solar extractor raised the efficiency of the extractor on an average about one per cent.

The addition of a lamp to the double glass extractor did not increase the efficiency of the extractor over 0.7 per cent.

Soaking the comb in water before using the solar extractor increased the yield of wax on an average, about one per cent.

The soaking of the comb in dilute (5 per cent) sulfuric acid increased the yield about five per cent over that not treated.

Of the steam wax extractors, the Root proved the best. The results show that for the same comb, number two, the Root produced one per cent more than the Ferris and ten per cent more than the Swiss.

Pressure applied to the comb under hot water gives a larger per cent wax than when the comb is pressed in steam. Heating with dilute sulfuric acid and pressing under water gave the best results. For number two comb this method excells in efficiency the single glass solar extractor by thirty-six per cent., the double glass solar by twenty-nine per cent., the Swiss steam wax extractor by eighteen per cent, the Ferris steam wax extractor by nine per cent, and the Root steam wax extractor by over seven per cent.

For number three comb, heating with dilute sulfuric acid and pressing under hot water, excells the single glass solar wax extractor by thirty-five per cent, the double glass solar wax extractor by about thirty-two per cent, the Swiss steam wax extractor by twenty-four per cent, the Ferris steam wax extractor by nineteen per cent, and the Root steam wax extractor by seven per cent.

The above shows that the slumgum from 100 pounds of wax treated by the ordinary solar wax extractor will retain from thirty-four to thirty-six pounds of wax, which can be removed by heating with dilute sulfuric acid and pressing under hot water. If the Root extractor, which is the best

of the steam wax extractors, is used there remains in the slumgum about seven pounds of wax which is obtainable by the use of the sulfuric acid and pressure. With the price of wax at twenty-five cents a pound it would pay to buy old slumgum and remove the wax by this method.

The method of heating the wax, while inclosed in a bag, with sulfuric acid, as practiced by more refiners of wax, gives good results.

Sulfuric acid seems to be better for bleaching wax than either hydrochloric acid, nitric acid, or a mixture of potassium bichromate and sulfuric acid. The wax from the latter has a dark green color which may be removed by repeated heating with oxalic acid. Oxalic acid is a poison and I am not prepared to state how much would be left in the wax or what effect it would have upon the bees working with the wax.

An increase of sulfuric acid above five per cent does not seem to improve the color of the wax.

The addition of five per cent of hydrogen peroxide to the sulfuric acid and water gives a much lighter colored wax. An increase of hydrogen peroxide above five per cent does not give an improvement in the color of the wax.

Common salt added to the water in which the wax is boiled does not cause the dirt to settle enough to show a change in the color of the wax.

Heating the wax, which has not been treated with sulfuric acid and potassium bichromate, with oxalic acid does not seem to improve the color of the wax.

Excessive boiling seems to injure the grain of the wax. The best results in regard to the grain of the wax were obtained by causing the wax to melt but not come to a boil.

Heating the wax while inclosed in a cloth and squeezing it after the wax has melted gives a much better colored wax than heating without the cloth. A fine canton flannel cloth with the nap inside is better than a coarse cloth. The nap seems to hold the dirt that is in the wax. Remelting the wax inclosed in a cloth with two per cent. solution of sulphuric acid and five per cent. hydrogen peroxide improves the color of the wax. Continued treatment in the same way does not give corresponding improvement in the color of wax. After the third treatment there is not any improvement in the color and rather a deterioration in the quality of the wax.

Boiling with concentrated and dilute alcohol does not improve the color of the wax.

The color of the wax is not improved by standing over water after cooling.

All of the slumgum retains some wax, but it was found impossible to determine the exact amount.

From the results of these experiments and my own experience in handling bees and rendering wax I believe that it is best for the average beekeeper to have a large solar wax extractor, heated by some artificial heat, by means of which most of the wax in the lighter colored combs, cappings, and burr combs may be easily rendered. The dark combs may also be treated in this manner and the slumgum stored in barrels until the beekeeper has time to treat it with dilute sulphuric acid and press under water. This method is quick and efficient. If the wax has to be refined it can be done by heating, while inclosed in a canton flannel sack, with a solution containing five per cent. of hydrogen peroxide and two to five per cent. of sulphuric acid. Both of these chemicals can be bought at the ordinary drug store. The common kind, commercial, should be used.

In mixing the acid and the water care should be taken to always pour the acid gently into the water and not the water into the acid.

The cost of the chemicals compared with the results obtained is very slight.