BEESWAX

THE FIX IT'S IN, AND A WAY TO FIX IT, PART 2

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Beeswax: a wondrous substance exuded from the bodies of bees to create a home complete with nursery, pharmacy, storeroom and vibrating communications center – prized and revered by humans since prehistoric times for light, protection and spiritual connection.

It comes dear to the bees. A strong nectar flow is needed to feed the young wax-exuding workers, and the cost to create a pound of beeswax is well over five pounds of honey – even double or triple that (Brown 1995, Whitcomb 1946, Coggshall and Morse 1984, Buchmann, unpubl). But what a marvel: That pound of wax, made into comb, can hold 22 pounds of stores (Brown 1995).

Pure beeswax is edible, pronounced safe for human consumption by the USDA, since it passes through the system unaltered. That makes it an ideal ingredient for medical preparations and cosmetics if it is pure. But, mostly, it is not pure. How impure it is was "mind-blowing" to Maryann Frazier, Chris Mullin and Jim Frazier, colleagues at Penn State University. They coordinated with Roger Simonds of the USDA Gastonia lab to screen hive samples for 171 pesticides and metabolites, breakdown products. They found chemicals pervasive (M. Frazier 2014).

"The wax is contaminated with pesticides. Pollen, the protein source fed to larvae, is also contaminated with pesticides. What bees are eating and what they are living in is contaminated; the hive is a toxic house," said Frazier (McNeil 2011). In the first 887 samples, 99% had detectable residues; they found 121 of the pesticides in the screen, some of which had not been registered for many years. Most often, and at the highest levels, were acaracides put into hives by beekeepers to control mites over nearly three decades (Mullin, 2010).

It turns out that honey bees are excellent biological indicators of the chemicals in their environment, and hive wax stores a record of chemical exposure that occurs both inside and outside their hives. Because most pesticides are lipophilic (attracted to/dissolving in lipids), they are absorbed in wax, a lipid. The Penn State study proved it to be an efficient sink: almost all beeswax samples (98%) were contaminated with pesticides, most commonly fluvalinate, coumaphos, amitraz degradates and chlorothalonil, a widely-used fungicide. Nearly 60% of the wax samples contained at least one systemic pesticide. Some pesticides in combination synergize to become more toxic or "swamp" the detoxification mechanisms of bees – for one common example, coumaphos combined with fluvalinate. Synergism is common with certain classes of fungicides and these miticides (Johnson 2009, Mullin et al 2010).

The detectives' detective – Roger Simonds at the National Science Laboratory, USDA Agricultural Marketing Service, worked out a protocol with the Penn State team for testing hive products for pesticide to parts per billion. He is pictured with a GC/MS/MS, gas chromatography-mass spectrometry machine, used to identify different substances within a test sample. (photo courtesy of Roger Simonds)

It matters a lot for the bees and their keepers. "Laboratory studies have clearly indicated sublethal impacts [of some pesticides] on honey bee learning, immune system functioning, and synergism of insecticide toxicity by fungicides," according to Mullin (Raloff 2010). Other research has indicated that pesticide residue in brood comb reduces adult longevity, enhances the reproduction of Varroa because of delayed emergence of adult bees, and increases susceptibility to pathogens (Wu, 2011).

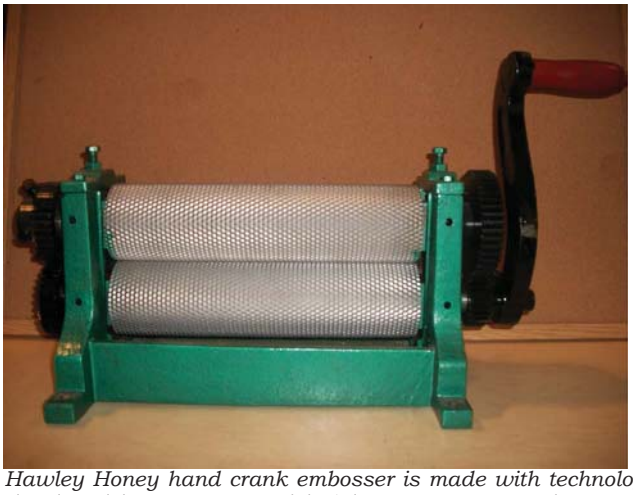
Finding Clean Foundation

Wax is the least renewable resource in the hive. Research labs have found that obtaining pure beeswax for comparative study has been an unexpected challenge. For example, in Part I of this article, University of Georgia researcher Jennifer Berry was left hunting for clean foundation to use as a control to examine the effect of miticides on bee health.

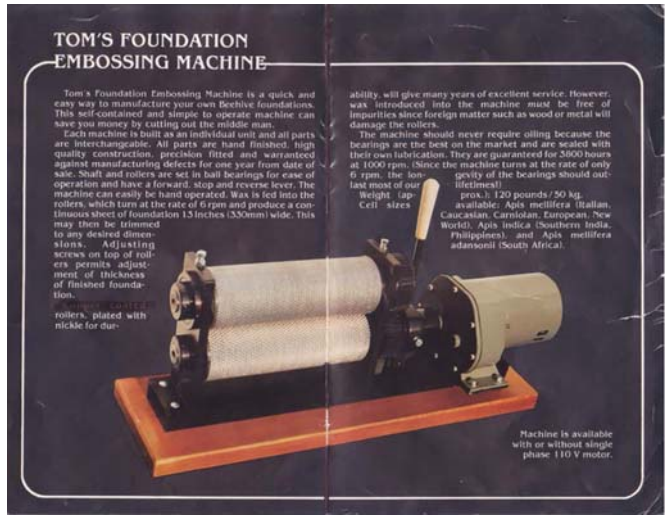
Roger Simonds is the go-to guy for chemical analysis of wax. His lab at the USDA-AMS-National Science Laboratory, using the analytical method developed with Mullin, can screen for commonly used pesticides and their metabolites to parts per billion (ppb). He detected chemical contamination in Jennifer Berry's samples from commercial sources, acaracide-free Brazil and even hives of her chemical-free beekeeping friends (Berry 2009).

The same problem faces beekeepers across the country. A variety of foundation samples analyzed by the Penn State researchers, via the USDA-AMS-National Science Laboratory, found all to be miticide contaminated with levels of coumaphos as high as 12.9 ppm and fluvalinate as high as 10.1 ppm. Wax removed from wax-coated plastic foundation had a coumaphos level of 6.3 ppm and fluvalinate level of 2.7 ppm and all foundation samples had additional pesticides at lower levels.

What to do about it? The answers seem to be: Find clean wax, clean up what we have or don't contaminate it in the first place. No simple choice. Here follows an attempt to sort out the unwieldy, impractical, crazy-making and just plain dangerous from some possible answers.



Hawley Honey hand crank embosser is made with technology developed by Tom Lazarevich. (photo courtesy Hawley Honey Co.



An informative brochure from Tom's Industries. Tom Lazarevich became expert in mill design, and his work was acquired by Hawley Honey after his death. (photo courtesy of Hawley Honey)

Find Clean Wax

The first place a beekeeper is inclined to look for clean wax is in untreated hives. It's not so easy. Pesticide residues quickly diffuse through wax or across comb surfaces in an active colony, as shown at the end of an experiment by researcher Judy Wu Smart at the University of Minnesota. She sent Simonds samples of comb used as an uncontaminated control; they were shown to have absorbed chemical residues over a three month period. Also, high levels of metabolites were detected, suggesting the possible metabolism of active compounds as the result of pesticide migration. Whether it came from contaminated bees or flowers, it was readily tracked through the frames (Wu 2014). Even after decades without hive treatments, Vermont beekeeper Kirk Webster said he was shocked when a lingering residue of coumaphos, which he used at a low dose once, many years ago, was detected.

Jennifer Berry gave up her quest to buy clean wax and used strips of plastic foundation along the frames, adding wire guides to allow the bees to build their own comb. It was a solution to the problem, but some crooked and joined comb made it an unwieldy one for her study (Berry 2013). Beekeepers who prefer to allow the bees to build their own comb, such as in top bar hives, can alternatively use melted wax or strips of beeswax as starting guides (Krell 1996). Penn State researchers use a technique adopted by a number of beekeepers: plastic foundation coated with wax analyzed and identified to be free of pesticides, or cappings wax in the case of beekeepers.

Cycling out old comb, where pesticide residues persist, is a widely recommended management technique for cleaning up toxicity in the hive (Berry and Delaplane 2001). But Wu's research shows that new comb, with weaker pheromones, is less attractive to nurse bees, negatively impacting the care of brood reared in it. So it's a tradeoff, with the balance in favor of housecleaning.

Foundation Molds

Foundation, a hexagon-embossed sheet of beeswax, provides a base or mid-rib in frames to guide cell construction into straight, movable combs for the beekeeper to work. Wax foundation is one of the few products not supplanted by synthetic waxes, which bees will not accept (Shimanuki 2007). Although plastic foundation and even frames are now ubiquitous, a study at Cornell University indicated that bees have a preference for drawing out beeswax foundation over plastic (Seeley 2006). Beekeepers have long deferred its difficult production to manufacturers, but, out of concern for contamination, the lost craft of small-scale foundation making has been revived.

The least expensive means for making foundation, although not necessarily the best, is with a mold. It can be made of plaster impressed with foundation patterns.[1] Silicone can provide a flexible impression; it is poured over a sheet of plastic or wax foundation fixed into a frame and allowed to set into a pliable sheet. The opposite side of the master is used to make the second part of the mold, which is then hinged to the first to align front and back – a tricky maneuver to make precise. A lightly soapy mold release is used before liquid wax is then poured into the mold to form a sheet of foundation.[2] Such molds are not replications but slightly smaller and more shallow than the originals, producing foundation that is yet another generation smaller than the molds. Foundation from molds is more brittle than milled foundation.

Milling Foundation

A foundation embossing mill is expensive, and using one requires some skill. That being said, it is being done by a growing number of beekeepers. It is an exacting process, as the two sides of the foundation sheet must match perfectly: the bottom of one cell precisely faces three opposite cells (Shimanuki 2007). A method called dip and roll is most often used for small-scale production, with control of foundation thickness acquired with practice. A workroom needs to be warm enough for wax to be malleable, about 70°-75°F (21°-24°C). A non-reactive container of melted wax needs to be heat controlled so that liquid wax will not run off dipping boards or adhere unevenly (Coggshall & Morse 1984).

"Learning to make foundation was the most difficult thing I ever did with bees," said Kirk Webster, who now makes 2000-3000 sheets of foundation with a hand cranked mill in the off-season. He concluded that the reason the bees were ignoring his foundation was that

Foundation is first poured into long molds and then fed into a mill at the Rare Hawaiian Honey Company. It is then cut to shape for inserting into frames. The company leases enough wild land to become certified organic, and their wax tested pesticide free by the USDA. (photo courtesy of Michael Domeier)

his machine was poorly made, so he replaced it with a well-crafted mill from Mennonite beekeeper Myron Kroeps, who offered helpful direction. "The difficult thing is getting the right temperatures", he said. "But it's not that complicated, once I got it figured out" (2014 personal communication).

He dips pieces of lauan plywood (also called meranti or Philippine mahogany) into a vertical vat of wax, keeping the wood cooler than the wax between dips by submerging in water. The number of dips in the hot wax determines the thickness of the wax sheets to be fed through the mill.

He produces about 400 sheets a day. He fastens the foundation into frames with two wires and two vertical sticks, after C.C. Miller. He does see more drone brood – an observation made by others with mills from different sources – but not enough to be detrimental.

He figures his expenses to be $.05-.07 per sheet – mostly for electricity to heat the vats and the workroom.

Don Kuchenmeister demonstrates foundation making with a video in which he says "Anyone can do it."[3] He keeps wax at about 172°F (78°C) in a commercial rectangular turkey roaster with a temperature gauge and a cooling water bath at 91-95°F (33°-35°C). Other beekeepers, like Robert MacKimmey and Volker Ackerman of Marin and San Francisco, make the wood dippers 1-2" larger than final size in order to trim edges and square the foundation. They dip the wood horizontally, finding it takes some practice, peel the wax off and re-dip it in warm water to soften before it is fed into their mill. They make it a two-person job, with one feeding in the sheet and cranking and the other pulling the sheet gently out of the rollers. "It's like making pasta," MacKimmey said.

Long wax sheets are prepared at the Rare Hawaiian Honey Company. They are fed into the foundation mill and loosely rolled until they are cut to shape. Deciding to move on from small cell foundation, which did not prove to be a *Varroa* preventative, owner Michael Domeier took a chance on buying a 5.1mm mill directly from China and reports that the bees build well on the foundation. The company, certified organic, leases 1000 undeveloped acres of state land where no pesticides are used. State apiarist Danielle Downey had the wax tested by the USDA, and it came back clean.[4]

Buying a Foundation Mill

Machines successfully cranking out foundation can have an arcane origin, with some from a hand craftsman who only occasionally makes one, and others from a long closed company. What is available now is not easily compared.

Hawley Honey, a company in the foundation machine business since 1942, is the only remaining domestic mill maker. Hawley had been buying embossing rollers from Rietsche in Germany, still a major foundation machine manufacturer. A company in Arizona, Tom's Industries, had perfected rollers over many years, so the acquisition of that company made it possible for the Hawley family to make complete machines (Moore 2014).

Erik Österlund, editor of the Swedish beekeeping journal "Bitidningen" has one of these machines and wrote: "Today Hawley Honey has some quite good mills from the design of Tom Lazarevic. There are some parts of a mill that are worth considering, the cell size, the cell walls and the cell bottoms. The most important part for getting foundation that the bees like and draw well is the angles in the cell bottom . . . a deep cell bottom as similar as possible to natural cell bottoms. But the manufacturers of mills and molds make a compromise here as the deeper the angles are, the more difficult it is to release the foundation . . . [so they make] mills with somewhat flatter cell bottoms. The Lazarevic type I would consider one of the best. If you consider buying ask for the Lazarevic type."[5]

At Hawley, a family business, it takes Robert Moore two to three weeks to build a small machine. It is off-season work, since he also keeps about 1500 colonies and delivers honey to over 100 stores. He makes large commercial machines, and three kinds of small-scale models that can be either hand cranked or machine driven. His father-in-law Raymond Cooper points out that they use heavy-duty bearings, and the mechanism for all the models is of the same quality.[6] They also make pre-rollers, called sheeters, for beekeepers who prefer not to use the dip method of preparing sheets for embossing.

Other sources: The hand-made mill by Myron Kropf in Arkansas has "good deep bottom angles", according to Österlund, however he produces very few. A mill from Mann Lake, manufactured in China, will be used by

A snowy Vermont day in a room warmed up for wax foundation making. As Kirk Webster cranks the mill, he pulls the embossed foundation sheet with a wood and plastic grip that is attached to a clamp. (photo by Dean Stiglitz)

Kirk Webster makes 2-3,000 sheets of foundation every year with his hand-cranked mill. The tube above feeds water into a homemade cylinder that drips onto the rollers, keeping them cool. (photo by Dean Stiglitz)

Karen Cosgrove at Cosnic Honey with the support of a sustainability grant from Kentucky State University.[7] A Chinese mill was bought direct by Rare Hawaiian Honey; several Chinese companies sell them through the website Abracadabra. Rietsche machines, made in Germany, are called by Weber "the Mercedes-Benz of mills".

A Cooperative Model

A beekeeping center, complete with a foundation-making facility, has been built by The Gorenska Beekeepers in the Slovenian city of Lesce.[8] Such foundation cooperatives were once common in the country. Beekeepers can have their wax processed there for €1.20 ($1.67) per kilo, which produces about 74 sheets of foundation. Small-scale beekeepers can pool wax to make the minimum 20 kg (about 45 pounds).

Importing Wax from Abroad

There is more demand for beeswax in the U.S. than can be satisfied domestically, as is the case for most industrial nations. A developing country producing certifiable uncontaminated wax would have a valuable export commodity, but such logistics have proven complex.

The acaricides prevalent in U.S. wax are not found in Australia because *Varroa* is not there. Foundation sheets ordered by California beekeeper Jerry Draper from the bee supply company John L. Guilfoyle, Ltd., outside of Brisbane, were found to contain one pesticide, the organophosphate insecticide chlorpyrifos, at 165ppb. The acute contact LD50 for honey bees is 762ppb. While 165 ppb is below the acute LD50, if bees were exposed to this level of chlorpyrifos in their wax combs we would expect to see some toxic effect due to the bioaccumulation that would occur over time.

Burt's Bees spokesperson says that the company sources wax from East Africa, but cannot specify the location or produce testing information.

A project in Kenya, with researchers from Penn State University (including author Frazier) and Nairobi-based *icipe* (International Center of Insect Physiology and Ecology), surveyed the major ecosystems for beehive numbers, parasites, pathogens and pesticides (Muli 2014). Kenya does not have migratory beekeepers, package producers or queen breeders. The honey bees, four subspecies of *Apis mellifera*, migrate with the seasons, and beekeepers put out bait hives in advance of the rainy season to hive them. The research team discovered *Varroa* there in 2009, and they have discouraged the use of acaracides (McNeil, 2011). Some agricultural chemicals were found in the wax, although mostly at low levels. A few locations were more toxic, such as one along the coast with nine residues, three of which, carbaryl, lindane and permethrin, are considered highly toxic to bees. The most wide-spread pesticide was the fungicide chlorothalonil. New samples from a subsequent recent trip are being analyzed with a goal of finding uncontaminated exportable wax to support a project designed to trade U.S. sponsored solar wax melters for clean wax.

Clean Up the Wax We Have

Many acaricides cannot be removed by rendering (Shimanuki 2007), washing or steaming, as is the case with other pesticides. Gamma irradiation had minimal results on lower pesticide levels at Penn State. Ozone was proposed in the early 40's at the USDA for decontaminating beeswax from American foul brood (K. Flottum, personal communication). Two new USDA studies have demonstrated that ozone gas fumigation can remove both pathogens and pesticides from beeswax comb (R. James 2011, 2013).

Ozone is an oxygen molecule with three oxygen atoms instead of two. Because it is unstable, it is a highly reactive, a strong oxidizer that breaks down into water and 0_2.[9] Ozone, a substance "generally recognized as safe" by the U.S. Food and Drug Administration, is used to decontaminate water, fruits and vegetables.

The studies, led by entomologist Rosalind James, were done in two parts at the ARS Pollinating Insect Research Unit in Logan, Utah. The first, published in 2011, demonstrated the efficacy of ozone at killing all life stages of the greater wax moth (at concentrations

BUYING FOUNDATION MILLS

Alibaba
Direct from China. Various manufacturers, specifications. Most plus shipping. **alibaba.com**

Dixie Bee Supply, Lula GA
Plastic rollers $1300, metal $2000 plus shipping. Unspecified origin. Don Kuchenmeister, Lula, GA, 706.677.3502, **beekeeper4u2@wmconnect.com**

Glory Bee, Eugene, OR
Metal rollers, non-adjustable, 4.9mm cell size, made in China. Comes with directions. $1500, plus shipping, 139 pounds. **http://www.glorybee.com/shop/Beeswax-Foundation-Mill.html**

Hawley Honey Company, Iola, KS
U.S. manufacturer, small to commercial, manual or machine driven, non-adjustable or adjustable, plastic or zinc plated rollers, 2 ½ inch or 3 ½ inch diameter, all with metal bearings, cell sizes 4.1, 4.9, 5.1 and 5.3mm. $800 to $2400 plus shipping, specific quotes made by phone. 620.360.5956.

Mann Lake, Hackensack, MN
Manually operated, two separate machines with aluminum rollers for sheeting and embossing, made in China, cell sizes 5.1mm or 4.9mm. $2,565, shipping included. **www.mannlakeltd.com**

Rietsche, Germany
Manufacturer, steel cylinders jacketed with embossed alloy, ball bearings, direct drive, comes with attached solvent sprinkler, cell size 5.4mm or special order (eg 4.8, 5.2, 5.6), manual from $4,600 to $6,400, motor driven from $6,750, prices dependent on roller length, plus tax and shipping. Extra cell depth for surcharge. Mills can be purchased prepared for a motor drive to be added later. **www.rietsche.de.**

of 215-430ppm, with eggs requiring longer exposure), chalkbrood fungus (at 1,500ppm for 24-36 hours), and American foulbrood (requiring doubling ozone concentration, high humidity and longer exposure). AFB bacterial spores are very resistant to chemical disinfectants and heat.[10]

The second part of the study, published in 2013, describes ozone breakdown of coumaphos, fluvalinate, and other pesticides that accumulate in beeswax. Lab experiments with ozone fumigation degraded 93-100% of coumaphos and 75-98% of fluvalinate (at 500ppm for 10-20 hours). Higher concentrations and longer exposure were required to reduce those acaracides as well as eight other common agricultural pesticides from samples of commercial comb -- including the insecticides esfenvalerate, (Conquer, Ortho Bug B Gon) and thymol, as well as the fungicide chlorothalonil (Fungonil, Daconil). Ozone significantly reduced dimethylphenyl formamide, chlorpyrifos, and fenpyroximate contaminations in comb.

Ozone treatments degraded pesticides considerably better in comb less than three years old than in comb more than 10 years old, leading the researchers to advise rotating aging comb out of the hive. "There's something about the wax that can impede this breakdown, especially in a comb that's been reused in hives for many years," says James.[11] She envisions beekeepers fumigating combs before they are placed in storage for the off season, possibly starting with new comb and treating it yearly to prevent pesticide residues from building up.

"Irradiation has to be done in a regulated facility," said James, "Whereas an ozone fumigation chamber is something beekeepers can set up on their own using commercially available equipment."

Beekeepers Elmer and Martin James conducted a field study for the USDA lab at their Slide Ridge Honey in Mendon, Utah. On the 8880 frames processed, nearly all pesticide residue was destroyed, herbicide residue destroyed, and wax moth destroyed. "Comb with severe wax moth damage has never been acceptable to our honey bees . . . but ozone treated, is very acceptable; the bees moved right onto it and started cleaning out the cells for reuse," said Elmer James. In the trial, success came with longer and stronger treatment than at the lab: nearly 100% of chalkbrood was killed in two days (1500ppm, 25°C [77°F]) and all American foulbrood spores in three days (4000 ppm, 50°C [122°F], 90% humidity).[12]

Even with these results, the James' are not ready to use ozone treatment again. An airtight chamber is required for ozone fumigation, as it is toxic to animals (humans included) at the concentrations used to kill pathogens and degrade pesticides – although it breaks down rapidly and harmlessly into oxygen and water. It is not safe for latex or rubber, and ozone leakage into the James' adjoining warehouse room damaged a stack of tires.

"The reason we tried ozone," said Elmer James, "Was because of used equipment we purchased from many different commercial beekeepers that had gone out of business, for reasons unknown...We were having dead-outs in a number of the brood boxes, the bees did not take to them; after O_3 treatment the bees were very content in these brood boxes – if O_3 treatment would salvage the equipment it was worth the expense." He observes that further research needs to be done on the amount of degradation of wax per amount of ozone applied.

The leased generator was $3000 per month and electricity $95 for the field study – making the cost per frame $.36, without counting the substantial labor. "If we were to use ozone again, we would use a freight container set far away from all other buildings. It appears that it would take the scale of large commercial beekeeping to offset the cost, or an agricultural co-op . . ." he said. [13]

That vision has come about: The Ontario Beekeepers' Association Tech Team and Parker Bee Apiaries have collaborated with the University of Guelph for an ozone honey comb decontamination pilot project, supported by a Canadian Federal Department of Agriculture grant.[14]

Mike Parker, a commercial beekeeper with 6,500 colonies, has seen his share of loss. Several years ago, he lost 90% of his stock.[15] He invested in the ozone project with an interest in reusing as much comb as possible, so most of the comb in the current experiment is older than three years, according to Tech Team member Devan Rawn.[16]

Two studies by Rosalind James, at the USDA-ARS lab in Utah, showed promise for the use of ozone treatment to rid beeswax comb of pathogens and pesticides. (photo courtesy Rosalind James)

They have contracted with Simpson Environmental Corporation, which specializes in ozone treatment for air and water, to design and install the mechanism. A retired refrigeration trailer, which can service multiple locations, was a quarter of the cost of insulating a freight container because it is already insulated with ozone-resistant claddings; also, it is considerably longer, making it possible to treat nine stacked pallets.[17] An equipment room at the front end with its own door, separate from the decontamination chamber, contains a Simpson-designed ozone generator, oxygen concentrators, and ozone destruction system. Controls raise the treatment chamber temperature to 40°C (104°F) and 60% humidity before injecting high concentration ozone into the air stream. Ozone resistant tubes are inserted into the combs at various levels to monitor the ozone levels up to and beyond 1000 ppm. The reefer has the capacity to treat about 800 combs per load, with dosages and durations to be determined by the results of the pilot. Test results are forthcoming from a lab at Guelph University for acaricides and three neonicotinoids, according to Rawn.

James Simpson describes the design as "revolutionary", and the company is in the process of patenting it.

There remains one more way to address the problem of miticide-contaminated beeswax – not putting pesticides into it to begin with. This will require effective alternatives to address the *Varroa* problem, not an easy mission. Nevertheless, management of hive pathogens and regulation of pesticides are under intense review by beekeepers with a goal of cleaning house for the bees. BC

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Endnotes

[1]**www.beekeeping.com/articles/us/small_beekeeping/equipment_plans.htm**

[2]Lloyd Ziegler **www.youtube.com/watch?v=gBrBzFTxu0I** Also, Garth Cambray **www.scienceinafrica.co.za/2006/february/beeswaxmould.htm**

[3]Youtube video: **www.youtube.com/watch?v=5lU3C4f2Xfc**

[4]Interview 5/2/14, Michael Domeier, Rare Hawaiian Honey Company

[5]Erik Österlund e-mail 5/1/2014

[6]Interview 5/1/14 interview, Raymond Cooper, Hawley Honey

[7]Interview 5/2/14Karen Cosgrove, Cosnic Honey

[8]Blomstedt, William (2014) A Beekeeping Education Center in Slovenia, American Bee Journal, February, 197-8.

[9]Elmer James PowerPoint 2008

[10]Bernhard Rietsche states that boiling for one hour at 125°C (257°F) in Rietsche sterilizing equipment will kill AFB. Personal communication, 5/2/14.

[11]R. James interview

[12]Ozone room constructed at Slide Ridge Honey, Mendon, Utah: 20' x 15' x 10'. Large ozone generator unit, double chamber type manufactured by 03 Company in Idaho.

[13]Elmer James personal communication, date.

[14]Simpson personal communication 3/22/14

[15]Niagra This Week.com "Parker is all about the bees" (2009) June 4.

[16]Interview Devan Rawn, Ontario Beekeepers Association Tech Team, 4/16/14.

[17]Simpson email Email: 3/25/14 James H. A. Simpson, Simpson Environmental **Corp.jsimpson@senvc.com** **simpsonj@look.ca**