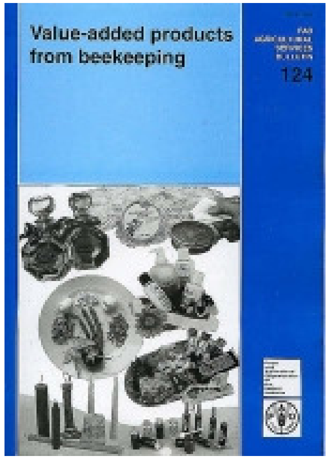

VALUE-ADDED PRODUCTS FROM BEEKEEPING

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by
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FOREWORD

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Many of the beekeeping activities in developing countries in the past have been oriented towards honey production. Wax usually was a by-product and other possible products have rarely found consideration. Such neglect of other products has a variety of reasons among which an easily accessible market or the lack of knowledge about production and further use are of major importance. While production methods of other primary products can be adapted from common beekeeping texts, the further elaboration and use of the same products can rarely be found. If so, descriptions range from highly specific scientific results to self-proclaimed experts fraudulently exploiting consumer ignorance. In order to present a comprehensive and practical review this bulletin tries to synthesize available information from scientific literature and practical, technical literature including the few in-depth reviews available on some of the primary bee products such as honey, Wax and propolis.

Worldwide the usage of such primary products as propolis, royal jelly and bee venom have increased mostly due to inclusion in cosmetic preparations. Medicinal use will increase once better and more detailed studies are completed, which however may not yet be in the very near future. The use of honey and other products has also increased in many countries because of the increasing health awareness and the high esteem of bee products in various processed and unprocessed forms.

In past publications the Agricultural Services Bulletins on beekeeping have sought to increase technical knowledge of beekeeping itself. During the last decades, the level of beekeeping and production knowledge in many developing countries has increased considerably. It was therefore considered necessary to provide further information for the expansion of beekeeping activities in order to increase income generation and stability as well as access to healthier products. Thus, this volume is intended to provide information on the utilization of all primary beekeeping products and in this way improve the possibilities for diversification in beekeeping activities. The new perspective for additional income generating activities for beekeepers and non-beekeepers alike may, under the right circumstances, also increase beekeeping viability in an otherwise often marginal business environment.

Most of the described products can also be produced by non-beekeepers, thus indirectly benefitting beekeeping by increasing the market for primary beekeeping products and opening opportunities for small, often home-based business activities.

Many of the described products can be produced with traditional skills on a very small, home-based production level but also on a medium to large industrial scale and are adapt for a variety of cultural and economic environments. This is very important since primary beekeeping products and their value added, processed products will increasingly have to find local markets, since international prices are too often below local production costs and require quality standards not easily reached by a young, developing industry. Diversification with value-added products therefore offers an opportunity to strengthen local markets which then permit a more solid beekeeping production to expand from a broad base into exportation. In this sense it is hoped that the provided information not only increases the viability and production of beekeeping and with it local living standards, but that it also can contribute to healthier products, import substitution and eventually increased incentives for regional and global trade.

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Dedication:

This book is dedicated to those ever laborious, wonderfiil little companions, the honeybees, that their labour will be appreciated with love by all those producing, using and consuming their unique products.

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CHAPTER 1

INTRODUCTION

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1.1 What are "value added" products from beekeeping?

The best known primary products of beekeeping are honey and wax, but pollen, propolis, royal jelly, venom, queens, bees and their larvae are also marketable primary bee products. While most of these products can be consumed or used in the state in which they were produced by the bees, there are many additional uses where these products form only a part of all the ingredients of another product. Because of the quality and sometimes almost mystical reputation and characteristics of most primary bee products, their addition to other products usually enhances the value or quality of these secondary products. For this reason, the secondary products, which partially, or wholly, can be made up of primary bee products, are referred to here as "value added" products from beekeeping.

Many of the primary beekeeping products do not have a market until they are added to more commonly used, value added products. Even the value of the primary products may increase if good use is made of them in other products, thereby increasing the profitability of many beekeeping operations.

In some cases the traditional and early technological uses of primary bee products have been replaced by other (often synthetic products) because of better availability, lower cost and/or easier processing. But in regard to food or health products, there are no synthetic substances which can substitute for the wide variety of characteristics of primary bee products. Only when it comes to highly specialized applications and conditions, will synthetics sometimes outperform these unique and versatile products. In that sense, all products containing one or several of the primary bee products are value added products. Furthermore, the combination of several bee products synergistically increases their beneficial significance beyond their individual biological values.

Since monetary resources are limited in many societies the additional value cannot always be obtained in the form of higher prices, but may show itself in the form of preferred purchases. For the same reasons though, some products may not be able to compete against cheaper synthetic products. In such cases, the added value and cost may make a product unsuitable, unless other markets can be found.

1.2 The purpose of this bulletin

The purpose of this bulletin is to distribute and make available information on the manufacturing, processing and marketing of value added bee products. It is directed at beekeepers as well as non-beekeepers, small entrepreneurs, extension officers and those involved in small business development. Therefore, it tries to provide enough information to understand the primary products and their present and potential use. It should also enable the reader to properly buy, store, process, package and market the primary products, as well as the value added products derived from them.

Traditionally, honey is considered the major beekeeping product. Wax has played a considerable role in only a few parts of the world and propolis is even less known. However, with increasing knowledge about beekeeping and an awareness of the beneficial aspects of many bee products, the use and demand for other products is increasing. The inclusion of "natural" bee products in cosmetics, medicines and foods has improved consumer appeal. While such appeal is not always based on scientific evidence, more and more studies confirm at least some of the traditionally claimed benefits of primary bee products.

This bulletin cannot be a scientific review of the rapidly increasing volume of research available, but it attempts to give a brief yet comprehensive overview of the current state of knowledge. Thus the reader should be able to make conclusions about the myriad of sometimes miraculous effects and cures claimed for bee products. References to more detailed articles, reviews and speciality journals are made to guide those whose interests go further.

It is also impossible in the context of this bulletin to give more than a summarized description of all the primary bee products. However, an attempt has been made to give enough information for the reader, including non-beekeepers, to understand the products and to be able to draw conclusions on their proper use.

Some of the value added products mentioned in this bulletin require advanced manufacturing technology. Many, if not most can be made on a small-scale but, like cosmetics, would benefit from better processing technology and specialized training for the manufacturers. The general philosophy behind this bulletin, however, is to stimulate creative experimentation with new and old products suitable for local markets and customer needs.

In addition to presenting the multitude of possible uses for bee products, it is hoped that the information provided can lead to more diversified and increased income for beekeepers. It should help to create small business opportunities for non-beekeepers and improve the health, nutrition and economic situation of beekeepers and those who are willing to choose alternatives to today's abundance of over-processed and/or synthetic drugs, cosmetics and foods.

Finally, the bulletin should stimulate beekeeping as a hobby and so may be a valuable source of recreation and relaxation.

1.3 How to use the bulletin

In the same way that two cooks, using the same recipe to produce different tasting dinners, the recipes and guidelines in this bulletin will produce different results in different places. Availability and quality of ingredients will vary from country to country, as will working conditions, customer preferences and marketing possibilities for the products. Therefore, the given recipes and recommendations have to be tried under local conditions. Recipes, ingredients, flavours, colours, consistencies, packaging and quality have to be adjusted to local markets. Where possible, alternatives and variations have been suggested.

The reader who is considering making beeswax candles or cosmetics should find enough information to decide whether he or she can physically, technically and economically afford to start the particular kind of production. Furthermore, he or she should be able to produce a variety of simple, good quality products with the information provided.

For most product categories there are more detailed and specialized publications available, which should be used to expand or improve a chosen activity. Since many of these books are expensive and in some countries difficult to obtain, as complete a picture as possible is presented in this bulletin. In addition, addresses of sources for books, laboratory tests, information and marketing assistance are given.

The goals of this bulletin therefore are to serve as a resource guide, a source of ideas and as a practical "cookbook" on products made with primary bee products.

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CHAPTER 2
HONEY 1

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2.1 Introduction

Honey is the most important primary product of beekeeping both from a quantitative and an economic point of view. It was also the first bee product used by humankind in ancient times. The history of the use of honey is parallel to the history of man and in virtually every culture evidence can be found of its use as a food source and as a symbol employed in religious, magic and therapeutic ceremonies (Cartland, 1970; Crane, 1980; Zwaeneprel, 1984) an appreciation and reverence it owes among other reasons to its unique position until very recently, as the only concentrated form of sugar available to man in most parts of the world. The same cultural richness has produced an equally colourful variety of uses of honey in other products (see Figure 2.1).

"Honey is the natural sweet substance produced by honeybees from the nectar of blossoms or from the secretion of living parts of plants or excretions of plant sucking insects on the living parts of plants, which honeybees collect, transform and combine with specific substances of their own, store and leave in the honey comb to ripen and mature. This is the general definition of honey in the Codex Alimentarius (1989) in which all commercially required characteristics of the product are described. The interested reader is also referred to other texts such as "Honey, a comprehensive survey" (Crane, 1975).

Honey in this bulletin, will refer to the honey produced by Apis mellifera unless otherwise specified. There are other honeybee species which make honey, and other bees and even wasps which store different kinds of honeys as their food reserves. More details on honey from other bees are given in section 2.11.

2.2 Physical characteristics of honey

Viscosity

Freshly extracted honey is a viscous liquid. Its viscosity depends on a large variety of substances and therefore varies with its composition and particularly with its water content (Table 2.1 and 2.2). Viscosity is an important technical parameter during honey processing, because it reduces honey flow during extraction, pumping, settling, filtration, mixing and bottling. Raising the temperature of honey lowers its viscosity (Table 2.3) a phenomenon widely exploited during industrial honey processing. Some honeys, however, show different characteristics in regard to viscosity: Heather (Calluna vulgaris) Manuka (Leptospermum scoparium) and Carvia callosa are described as thixotrophic which means they are gel-like (extremely viscous) when standing still and turn liquid when agitated or stirred. By contrast a number of Eucalyptus honeys show the opposite characteristics. Their viscosity increases with agitation.

Figure 2.1: A display of various products in which honey is an ingredient.

Table 2.1:

Variation of the viscosity of honey at 25^{0}C, containing 16.5% water, according to the botanical origin and therefore the composition of the honey (Munro, 1943).

Type	Viscosity (poise)
Sage	115
White clover	94

Sweet clover	87

Table 2.2:
Variation of the viscosity of white clover honey at 250 C according to its water content (Munro, 1943).

Water content (%)	Viscosity (poise)
13.7	420
15.5	138
18.2	48
20.2	20

Table 2.3:
Viscosity of sweet clover honey containing 16.1% water according to temperature (Munro, 1943).

Temperature (�C)	Viscosity (poise)
13.7	600.0
20.6	189.6
29.0	68.4

39.4	21.4
48.1	10.7
71.1	2.6

Density

Another physical characteristic of practical importance is density. Honey density, expressed as specific gravity in Table 2.4, is greater than water density, but it also depends on the water content of the honey (Table 2.4). Because of the variation in density it is sometimes possible to observe distinct stratification of honey in large storage tanks. The high water content (less dense) honey settles above the denser, drier honey. Such inconvenient separation can be avoided by more thorough mixing.

Table 2.4:
True specific gravity of honeys with different water content (White, 1975a).

Water content (%)	Specific gravity at 20�C	Water content (%)	Specific gravity at 20�C	Water content (%)	Specific gravity at 20�C
13.0	1.4457	16.0	1.4295	19.0	1.4101
14.0	1.4404	17.0	1.4237	20.0	1.4027
15.0	1.4350	18.0	1.4171	21.0	1.3950

Hygroscopicity

The strongly hygroscopic character of honey is important both in processing and for final use. In end products containing honey this tendency to absorb and hold moisture is often a desired effect such as, for example, in pastry and bread. During processing or storage however, the same hygroscopicity can become problematic, causing difficulties in preservation and storage due to excessive water content. From Table *2.5* it can be readily seen that normal honey with a water content of 18.3 % or less will absorb moisture from the air at a relative humidity of above 60%.

Table 2.5
Approximate equilibrium between relative humidity (RH) of ambient air and water content of a clover honey (White, 1975a).

Air (%RH)	Honey (% water content)
50	15.9
55	16.8
60	18.3
65	20.9
70	24.2
75	28.3
80	33.1

Surface tension

It is the low surface tension of honey that makes it an excellent humectant in cosmetic products The surface tension varies with the origin of the honey and is probably due to colloidal substances. Together with high viscosity, it is responsible for the foaming characteristics of honey.

Thermal properties

For the design of honey processing plants its thermal properties have to be taken into account. The heat absorbing capacity, i.e. specific heat, varies from *0.56* to 0.73 cal/g/^{0}C according to its composition and state of crystallization. The thermal conductivity varies from 118 to 143 x 10-~ cal/cm^2/sec/^{0}C (White, 1975a). One can therefore calculate the amount of heat, cooling and mixing necessary to treat a certain amount of honey, i.e. before and after filtration or pasteurization. The relatively low heat conductivity, combined with high viscosity leads to rapid overheating from point-heat sources and thus the need for careful stirring and for heating only in water baths.

Colour

Colour in liquid honey varies from clear and colourless (like water) to dark amber or black (see Figure 2.2). The various honey colours are basically all nuances of yellow amber, like different dilutions or concentrations of caramelized sugar, which has been used traditionally as a colour standard. More modern methods for measuring honey colour are described below. Colour varies with botanical origin, age and storage conditions, but transparency or clarity depends on the amount of suspended particles such as pollen. Less common honey colours are bright yellow (sunflower) reddish undertones (chestnut) greyish (eucalyptus) and greenish (honeydew). Once crystallized, honey turns lighter in colour because the glucose crystals are white. Some of the honeys reportedly "as white as milk" in some parts of East Africa are finely crystallized honeys which are almost water white, i.e. colourless, in their liquid state.

The most important aspect of honey colour lies in its value for marketing and determination of its end use. Darker

honeys are more often for industrial use, while lighter honeys are marketed for direct consumption. In many countries with a large honey market, consumer preferences are determined by the colour of honey (as an indication of a preferred flavour) and thus, next to general quality determinations, colour is the single most important factor determining import and wholesale prices.

Honey colour is frequently given in millimetres on a Pfund scale (an optical density reading generally used in international honey trade) or according to the U.S. Department of Agriculture classifications (White, 1975c and Crane, 1980):

USDA colour standards	**Pfund scale (mm)**
- water white	0 to 8
- extra white	> 8 to 17
- white	> 17 to 34
- extra light amber	> 34 to 50
- light amber	> 50 to 85
- amber	> 85 to 114
-darkamber	> 114

Figure 2.2: Different coloured honeys of unifloral and multifloral origin. (courtesy of F. Intoppa)

More recent but not widely practised methods of colour description use spectral colour absorption of honey (Aubert and Gonnet, 1983; Rodriguez L6pez, 1985).

Crystallization

Crystallization is another important characteristic for honey marketing, though not for price determination. In temperate climates most honeys crystallize at normal storage temperatures. This is due to the fact that honey is an oversaturated sugar solution, i.e. it contains more sugar than can remain in solution. Many consumers still think that if honey has crystallized it has gone bad or has been adulterated with sugar.

The crystallization results from the formation of monohydrate glucose crystals, which vary in number, shape, dimension and quality with the honey composition and storage conditions. The lower the water and the higher the glucose content of honey, the faster the crystallization. Temperature is important, since above 25 ° and below 5 °C virtually no crystallization occurs. Around 14°C is the optimum temperature for fast crystallization, but also the presence of solid particles (e.g. pollen grains) and slow stirring result in quicker crystallization (see 2.12.2). Usually, slow crystallization produces bigger and more irregular crystals.

During crystallization water is freed. Consequently, the water content of the liquid phase increases and with it the risk of fermentation. Thus, partially crystallized honey may present preservation problems, which is why controlled and complete crystallization is often induced deliberately. In addition, partially crystallized or reliquified honey is not an attractive presentation for retail shelves (see Figure 2.3).

a)

b)

Figure 2.3: Honeys in different stages of crystallization, (a) fermentation in partially crystallized honey and (b) different stages of reliquification after previous crystallization due to storage over very long periods of time or at relatively high temperatures. These unattractive changes can be avoided by controlled crystallization, proper storage and possibly pasteurization. (courtesy of F. Intoppa)

2.3 The composition of honey

The average composition of American honeys, more or less representative of all honeys, is shown in Table 2.6. Table 2.7 lists the various components identified in honeys from all around the world.

Sugars account for 95 to 99% of honey dry matter. The majority of these are the simple sugars fructose and glucose which represent *85-95%* of total sugars. Generally, fructose is more abundant than glucose (see Table 2.6). This predominance of simple sugars and particularly the high percentage of fructose are responsible for most of the physical and nutritional characteristics of honey. Small quantities of other sugars are also present, such as disaccharides (sucrose, maltose and isomaltose) and a few trisaccharides and oligosaccharides. Though quantitatively of minor importance, their presence can provide information about adulteration and the botanical origin of the honey.

Water is quantitatively the second most important component of honey. Its content is critical, since it affects the storage of honey. Only honeys with less than 18% water can be stored with little to no risk of fermentation. The final water content depends on a number of environmental factors during production such as weather and humidity inside the hive, but also on nectar conditions and treatment of honey during extraction and storage. It can be reduced before or after extraction by special techniques (see 2.6.9).

Among the minor constituents organic acids are the most important and of these gluconic acid, which is a by-product of enzymatic digestion of glucose, predominates. The organic acids are responsible for the acidity of honey and contribute largely to its characteristic taste.

Minerals are present in very small quantities, potassium being the most abundant. Dark honeys, particularly honeydew honeys are the richest in minerals.

Other trace elements include nitrogenous compounds among which the enzymes originate from salivary secretions of the worker honeybees. They have an important role in the formation of the honey. Their commercial

importance is not related to human nutrition, but to their fragility and uniqueness. Thus their reduction or absence in adulterated, overheated or excessively stored honeys serves as an indicator of freshness. The main enzymes in honey are invertase (saccharase) diastase (amylase) and glucose oxidase.

Traces of other proteins, enzymes or amino acids as well as water soluble vitamins are thought to result from pollen contamination in honey.

Virtually absent in newly produced honey, hydroxvmethylfurfural (HMF) is a byproduct of fructose decay, formed during storage or during heating. Thus, its presence is considered the main indicator of honey deterioration.

Even though some of the substances responsible for honey colour and flavour have been identified (see Table 2.7) the majority are still unknown. It is more than likely that honeys from different botanical origins contain different aromatic and other substances which contribute to the specific colours and flavours and thus allow to distinguish one honey from another. Similarly, it is very likely that, depending on their botanical origin, honeys contain traces of pharmacologically active substances. Some of them have been identified, such as those responsible for the toxicity of certain honeys (see also section 2.9), but for the majority of possible substances, scientific verification requires further studies.

Table 2.6
Average composition of U.S honeys and ranges of values (White, et al., 1962)

Component (% except pH and diastase valute)	Average	Standard deviation	Range
Water	<>17.2	1.5	13.4 - 22.9
Fructose	38.2	2.1	27.2 - 44.3

Glucose	31.3	3.0	22.0 - 40.7
Sucrose	1.3	0.9	0.2 - 7.6
Maltose (reducing disaccharides calculated as maltose)	7.3	2.1	2.7 - 16.0
Higher sugars	1.5	1.0	0.1 - 8.5
Free acids (as gluconic acid)	0.43	0.16	0.13 - 092
Lactone (as glucolactone)	0.14	0.07	0.0 - 0.37
Total acid (as gluconic acid)	0.57	0.20	0.17 - 1.17
Ash	0.169	0.15	0.020 - 1.028
Nitrogen	0.041	0.026	0.000 - 0.133
pH	3.91	-	3.42 - 6.10
Diastase value	20.8	9.8	2.1 - 61.2

2.4 The physiological effects of honey

2.4.1 Unconfirmed circumstantial evidence

For thousands of years honey was the only source of concentrated sugar. uniqueness, scarcity and desirability connected it to divinity very early in human history thus ascribing to it symbolic, magic and therapeutic significance. Much of the myth many of the traditional medicinal uses have continued until today.

Few of these medicinal benefits have seen scientific confirmation and they are not always exclusive to honey. The majority are due to the high sugar content and therefore can also be found in other sweet substances with high sugar contents. It was not by accident that sugar, when first introduced to Europe, was considered a medicine for many diseases and was used with caution.

The major properties and effects commonly attributed to honey (Donadieu, 1983) are briefly described below, but there are hundreds of different local uses in various countries, according to the specific cultures and traditions, and it is impossible to mention all of them. The Koran also mentions several uses for honey and other bee products (El Banby, 1987).

Nutritional benefits

Honey is said to facilitate better physical performance and resistance to fatigue, particularly for repeated effort; it also promotes higher mental efficiency. It is therefore used by both the healthy and the sick for any kind of weakness, particularly in the case of digestive or assimilative problems. Improved growth of non-breast fed newborn infants, improved calcium fixation in bones and curing anaemia and anorexia may all be attributed to some nutritional benefit or stimulation from eating honey.

Benefits to the digestive apparatus

Honey is said to improve food assimilation and to be useful for chronic and infective intestinal problems such as constipation, duodenal ulcers and liver disturbances. Salem (1981) and Haffejee and Moosa (1985) have reported successful treatment of various gastrointestinal disorders.

Benefits to the respiratory system

In temperate climates and places with considerable temperature fluctuations, honey is a well known remedy for colds and mouth, throat or bronchial irritations and infections. The benefits, apart from antibacterial effects, are assumed to relate to the soothing and relaxing effect of fructose.

Benefits to skin and wound healing

Honey is used in moisturizing and nourishing cosmetic creams, but also in pharmaceutical preparations applied directly on open wounds, sores, bed sores, ulcers, varicose ulcers and burns. It helps against infections, promotes tissue regeneration, and reduces scarring also in its pure, unprocessed form (Hutton, 1966; Manjo, 1975; Armon, 1980 and Dumronglert, 1983). If applied immediately, honey reduces blistering of burns and speeds regeneration of new tissue. Many case histories are reported in the literature for human as well as veterinary medicine (sores, open wounds and teat lesions in cows). A cream, applied three times per day and prepared from equal parts of honey, rye flour and olive oil, has been successfully used on many sores and open wounds -even gangrenous wounds in horses (Lu~hrs, *1935).* Lu cke (1935) successfully tested a honey and cod liver oil mixture suspended in a simple non-reactive cream base on open wounds in humans, but he gave no details on proportions.

Table 2.7:
List of coupoponds found in honey, but not necessarily present in all honeys
(from Gonnet and Vache, 1985 modified with data from Withe,
1975b Bogdanov and Crane, 1990)

Carbohydrates (75-80 %)	Acids (0.1-0.5 %)	Proteins and amino acids (0.2-2 %)	Minerals (0.1-1.5 %)	Vitamins	Aroma constituents		Others
Monosaccharides (70-75 %): Fructose Glucose Disaccharides: Maltose Isomaltose Saccharose Nigerose Turanose Maltulose Kojibiose Neotrehalose Gentiobiose Laminaribiose 2 Ketoses, unidentified Higher saccharides: Melizitose Erlose 1-kestose Raffinose Panose Isopanose Maltotriose Isomaltotriose Isomaltotetraose Isomaltopentaose Centose	Gluconic acid (70-80 % of total acids) Acetic acid Butyric acid Citric acid Formic acid Lactic acid Maleic acid Malic acid Oxalic acid Pyroglutamic acid Succinic acid Fumaric acid Tartaric acid α-Ketoglutaric acid probably present: α- or β-glycerophosphate glycolic acid glucose-6-phosphate 2- or 3-phosphoglyceric acid pyruvic acid	Different types of proteins of bee and plant origin Free amino acids: Proline Lysine Histidine Arginine Aspartic acid Threonine Serine Glutamic acid Glycine Alanine Cystine Valine Methionine Isoleucine Leucine Tyrosine Phenylalanine Tryptophan	Potassium Sodium Calcium Magnesium Iron Copper Manganese Chlorine Phosphorous Sulphur Aluminum Iodine Boron Titanium Molybdenum Cobalt Zinc Lead Tin Antimony Chromium Nickel	Ascorbic acid Riboflavin Pantothenic acid Niacin Thiamine Pyridoxine Biotin Folic acid **Enzymes** Diastase (α- and β-amylase) Invertase (glucoinvertase, but also very small amounts of fructoinvertase) Glucose oxidase Catalase Acid phosphatase shown to be absent: Lactase Protease Lipase	Esters: Methyl formate Ethyl formate Methyl acetate Ethyl acetate Propyl acetate Isopropyl acetate Ethyl propionate Methyl butyrate Ethyl butyrate Isoamyl butyrate Methyl valerate Ethyl valerate Methyl isovalerate Methyl pyruvate Methyl benzoate Ethyl benzoate Methyl phenylacetate Ethyl phenylacetate Methyl anthranilate Diethyl ether	Ketones and aldehydes: Formaldehyde Acetaldehyde Propionaldehyde Butyraldehyde Isobutyraldehyde Valeraldehyde Isovaleraldehyde Capronaldehyde Benzaldehyde Methacrolein Acetone (dimethyl ketone) Acetoin Methylethyl ketone Diacetyl Furfural 5-hydroxymethyl furfural HMF) Alcohols: Methanol Ethanol Propan-1-ol Propan-2-ol Butan-1-ol Butan-2-ol Isobutanol 2-methyl-1-butanol 3-methyl-butan-1-ol 3-methyl-butan-2-ol Pentan-1-ol Pentan-2-ol β-methallyl alcohol 2-phenylethanol Benzyl alcohol 3-phenylpropan-1-ol 4-phenylbutan-1-ol Furfuryl alcohol	Lipids: Glycerides Sterols Phospholipids Palmitic acids Oleic acid Lauric acid Myristoleic acid Stearic acid Linoleic acid Polyphenols Toxic substances (occasionally) Choline Acetyl choline Pinocembrin Traces of beeswax Microscopic particles: Pollen Fungal spores Bacterial spores Algal cells Yeasts

Benefit to eye disorders

Clinical cases or traditional claims that honey reduces and cures eye cataracts, cures conjunctivitis and various afflictions of the cornea if applied directly into the eye, are known from Europe (Mikhailov, *1950),* Asia, and Central America. This is said to be more true for Meliponid and Trigonid honeys from South and Central America and India. There are also case histories of ceratitis rosacea and corneal ulcers, healed with pure honey or a 3 % sulphidine ointment in which Vaseline was replaced by honey.

Medicine-like benefit

Frequently, specific benefits of unifloral honeys are reported, based on the traditional assumption that honey made from the nectar of a medicinal plant has the same or similar beneficial activity as the one recognized for the whole plant or some parts of it. Even if no transfer of active ingredients is involved, mechanisms similar to homeopathic potentiation are possible. Empirically effective therapies such as Bach flower therapy and aroma-therapy suggest that there can be much more to the medicinal value of honey than chemical analysis and quantification reveals. These claims are not supported by orthodox scientific evidence.

Diabetes

Frequently, claims are voiced that honey is good for diabetics. This is unlikely to find confirmation because of its high sugar content. However, it is better than products made with cane sugar, as a study by Katsilambros et al., (1988) has shown. It revealed that insulin levels were lower when compared to the uptake of equal caloric values of other foods, but blood sugar level was equal or higher than in the other compared products shortly after eating. In healthy individuals, the consumption of honey produced lower blood sugar readings than the consumption of the same quantity of sucrose (Shambaugh et al., 1990).

Ayurvedic medicine

Traditional, but well-studied medicinal systems as the ayurvedic medicine of India, use honey predominantly as a vehicle for faster absorption of various drugs such as herbal extracts. Secondarily, it is also thought to support the treatment of several more specific ailments, particularly those related to respiratory irritations and infections, mouth sores and eye cataracts. It also serves as a general tonic for newborn infants (see also section 2.9), the young and the elderly, the convalescent and hard working farmers (Nananiaya, 1992, personal communication). In general, no distinction is being made between honey from Apis mellifera A. cerana or A. dorsata.

Other benefits

Honey is said to normalize kidney function, reduce fevers and help insomnia. It is also supposed to help recovery from alcohol intoxication and protect the liver; effects also ascribed to fructose syrups. Heart, circulation and liver ailments and convalescent patients in general improved after injection with solutions of 20 and 40% honey in water (Kaul, 1967).

2.4.2 Scientific evidence

According to scientific evidence it would be better to consider honey as a food, rather than a medicine. Most of the benefits described above, at least for internal use, can most likely be ascribed to nutritional effects of some kind. On the other hand, our scientific understanding of cause and effect, typically only confirmed if a single compound measurably affects a well defined symptom, is far too limited to explain possibly more complex and subtle, particularly synergistic interactions.

Energy source

As food, honey is mainly composed of the simple sugars fructose and glucose, which form the basis of almost all indications on how, when and why to use it. The main consideration is the fact that honey provides immediately available calories, from which it derives its energy value for healthy and sick people: quick access to energy without requiring lengthy or complicated digestive action. The same direct absorption also carries a risk of pathological sugar metabolism, such as diabetes and obesity.

Non-energetic nutrients

Often honey is recommended because of its content of other nutrients like vitamins and minerals, but their quantity is so low that it is unrealistic to think they can provide any significant supplement in a deficient diet (Table 2.8). Similar arguments are made for the nutritional and health benefits from most other bee products, particularly pollen and royal jelly. Although their beneficial characteristics have been shown in numerous cases, they cannot be based on simple numeric values, i.e. X amount of substance Y. Yet, it is well known that the quality and availability of a nutrient is important for its usefulness to the body. Micronutrients in unprocessed honey can

be assumed to be of the highest quality possible. Thus from a nutritional point of view, a synergistic balancing effect or one that unlocks the availability of other nutrients already present, is one of the more plausible yet untested hypotheses.

Topical applications

Topical applications under controlled conditions have shown accelerated wound healing in animals (Bergman et al., 1983, El Banby et al. 1989) and of experimental burn wounds in rats (Burlando, 1978) but also of various types of wounds, including post-operative ones in humans (Cavanagh et al., 1970; Kandil et al., 1987a, b and 1989; Effem, 1988 and Green, 1988). Similar, yet not equal, effects are obtained with the application of purified sucrose and special polysaccharide powders (Chirife et al., 1982). External as well as internal wounds from operations become bacteriologically sterile within a few days and dry out. The simultaneous stimulation of tissue regeneration by honey reduces scarring and healing times. In addition, dressings applied with honey do not stick to the wounds or delicate new skins. In many tropical field hospitals, where antibiotics and other medicines are scarce, honey has been employed successfully for a long time.

Table 2.8:
Nutrients in honey in relation to human requirements (Crane, 1980)

Nutrient	Unit	Average amount in 100 g honey	Recommended daily intake
Energy equivalent	kcal	304	2800
Vitamins			
A	I.U.	-	5000

B1 (Thiamin)	mg.	0.004 - 0.006	1.5
B2 (Riboflavin)	mg.	0.002- 0.06	1.7
Nicotinic acid (niacin)	mg.	0.11.- 0.36	20
B6 (Pyridoxine)	mg.	0.008 - 0.32	2.0
Pantothenic acid	mg.	0.02 - 0.11	10
Bc (Folic acid)	mg.	-	0.4
B12 (Cyanocobaltamine)	mg.	-	6
C (Ascorbic acid)	μg	2.2 - 2.4	60
D	mg.	-	400
E (Tocopherol)	I.U.	-	30
H (Biotin)	I.U.	-	0.3
Minerals	mg.		
Calcium	mg.	4 - 30	1000
Chlorine	mg.	2 - 20	
Copper	mg.	0.01 - 0.1	2.0

Iodine	mg.	-	0.15
Iron	mg.	1. - 3.4	18
Magnesium	mg.	0.7 - 13	400
Phosphorous	mg.	2 - 60	1000
Potassium	mg.	10 - 470	-
Sodium	mg.	0.6 - 40	-
Zinc	mg.	0.2 0.5	15

Antibacterial activity

Antibacterial activity is the easiest to test and is probably the most studied biological activity of honey. In normal honey it is attributed to high sugar concentration and acidity (pH range 3.5 to 5.0). Yet, since also diluted honey has shown antibacterial activity, the active ingredient was attributed to an elusive substance generically termed "inhibin". Much of this activity was later attributed to hydrogen peroxide (H_20_2) an enzymatic by-product during the formation of gluconic acid from glucose. The responsible enzyme, glucose oxidase is basically inactive in concentrated normal honey. Thus, in honey solutions (diluted honey) with the right pH, antibacterial activity is largely due to the presence of hydrogen peroxide. The biological significance of such a mechanism arises from the requirement to protect immature honey (with high moisture content) inside the colony until higher sugar concentrations are achieved.

Both mechanisms can partially explain the sterilizing effect of honey on wounds and some of its efficacy against

cold infections, but it does not explain its beneficial effect on burn wounds (Heggers, et al., 1987) and faster wound healing with less scarred tissue. Subralimanyam (1993) has experienced 100% acceptance of skin grafts after storage in honey for up to 12 weeks. Antibacterial activity varies greatly between different types of honey (Dustmann, 1979; Revathy and Banerji, 1980; Jeddar et al., 1985 and Molan et al., 1988). In addition to glucose oxidase, honey seems to contain other mostly unknown substances with antibacterial effects, among which are polyphenols. These other factors have been identified in a few cases (Toth et al., 1987; Bogdanov, 1989 and Molan et al., 1989) but as a whole there are few scientific studies on the various claims of the beneficial effects of honey. However, it has been well demonstrated that most of the antibacterial activities of honey are lost after heating or prolonged exposure to sunlight (Dustmann, 1979).

Information sources on honey therapy

Mladenov (1972) published a book (in Rumanian) on honey therapy in Rumania and there are several articles on honey therapy in Apimondia (1976) as well as in Crane (1975 and 1990). The American Apitherapy Society collects case histories and scientific information on all therapeutical uses of bee products.

2.5 The use of honey today

2.5.1 As a food

Honey is most commonly consumed in its unprocessed state, i.e. liquid, crystallized or in the comb. In these forms it is taken as medicine, eaten as food or incorporated as an ingredient in various food recipes.

However, honey is considered a food only in a few societies such as those of the industrialized countries in Europe and North America, Latin America, North Africa, the Near East and increasingly in Japan. In most parts of Africa it is used for brewing honey beer and to a much lesser degree, as medicine. In most of Asia it is generally regarded as a medicine or at most an occasional sweet. High per capita consumption in industrialized nations (see 2.10) does not reflect the consumption of unprocessed honey per person but includes a very large quantity of honey used in

industrial food production, i.e. as a food ingredient.

In order to increase consumption and to make the various honeys more attractive, a large variety of packaging and semi-processed and pure honey products are marketed. Though they are strictly still "only" honey, their form of presentation can add a certain value to the primary product and is therefore briefly discussed here. One of the more appreciated forms, price wise at least, of selling natural honey seems to be honey in its natural comb. Including pieces of comb honey in jars with liquid honey (chunk honey) is very attractive to many consumers and appears to disperse suspicions of adulteration. Creamed honey (soft, finely crystallized honey) is a very pleasant product which is convenient in use because it does not drip. Honey is sometimes "enhanced" by adding pollen, propolis and/or royal jelly without changing the state of the honey itself. These products are described in the pollen, propolis and royal jelly chapters. For other "improvements" in the form and size of packaging see section 2.6.11.

In some countries the appearance of the marketed honey is not very important, i.e. it may be liquid, crystallized or semi-crystallized and with or without wax particles etc. Therefore it can be bottled as it is. In other countries, consumers want not only clean honey but also prefer liquid honey. Consumer education may change this attitude, particularly where it is based on the widespread but false belief that honey crystallizes because it is adulterated with sugar. To remain liquid however, many honeys require special processing (see 2.12.1).

Slow crystallizing honeys can be sold without further processing or may be used, if lightly coloured, to pour around bottled chunks of comb honey or fruits and nuts. Light coloured honeys are particularly suitable for sale as comb honey in special clear packages (see Figure 2.16 a). But any kind of honey can be sold as comb honey as long as the combs are evenly sealed and relatively new, i.e. with white or light yellow wax. In blending different honeys, attention has to be paid to the final ratio of glucose to fructose and the possible need for additional heat treatments Fast and slow crystallizing honeys low in moisture content can be processed to prolong their liquid state (see section 2.12.1) or can be forced to crystallize under controlled conditions to achieve a soft and uniform consistency (see section 2.12.2).

Uniformly crystallized honey is attractive both visually and for its convenience of use. It is also less likely to ferment than badly crystallized or semi-crystallized honeys (see Figure 2.3). Different storage temperatures in different climates, among other factors influence the crystallization and speed of re-liquefaction of honeys. Stored above 25�C, most honeys remain liquid or reliquify slowly, but lose much of their aroma in just a few months

2.5.2 As a food ingredient

The traditional use of honey in food preparations has been substituted in most cases by sugar and more recently by various sugar syrups derived from starches. These exhibit similar composition and characteristics, but at a much reduced cost. At the same time, as part of the increasing appreciation of more natural products in many countries, honey has been "rediscovered" as a valuable food and therefore confers, also as an ingredient, an enhanced market value to the end product. Many honey containing industrial products which were developed in the last decades, but which did not have the expected success, are currently being remarketed more successfully.

Outside of the thousands of "home-made" recipes in each cultural tradition, honey is largely used on a small scale as well as at an industrial level in baked products, confectionary, candy, marmalades, jams, spreads, breakfast cereals, beverages, milk products and many preserved products. In particular, the relatively new industry of "natural", health and biological products uses honey abundantly as the sweetener of first choice, together with non-refined sugars in substitution of refined sucrose (cane and beet sugar). In fact, honey can substitute all or part of the normal sugar in most products (see 2.12.11). Limitations are presented on one side by costs and handling characteristics and on the other by the natural variations in honey characteristics which change the end product, make it more variable and require more frequent adjustments in the industrial formulations (recipes).

Recipe books for home use of honey have been published in many languages. Many of these recipes can also be adapted for artisanal and small scale production. Aside from the occasional information in special trade books or journals, information or recipes about large-scale uses of honey are difficult to find. One French text on industrial food production with honey is a good source (Paillon, 1960). Otherwise the National Honey Board of the USA (see Annex 2) is able to provide information and technical assistance including tips on promotion and marketing, to

small and large industrial users of honey.

To <u>baked</u> products, aside from the already mentioned consumer appeal, honey confers several other advantages such as a particular soft, spongy (springy) consistency which persists longer. Products that contain honey also dry out more slowly and have a lesser tendency to crack. These properties are due to the hygroscopicity of honey, a trait honey has in common with other sweeteners high in fructose, like acid-hydrolysed corn syrup or other syrups made from starches and fruit juices. Another advantage consists of more uniform baking with a more evenly browned crust at lower temperatures. These characteristics too, are mostly due to the fructose content. Yet another advantage is an improved aroma, conferred by relatively small percentages of honey (up to 6% by weight of the flour) in sweet cakes, biscuits, breads and similar products (see Figure 2.4). Since most beneficial effects can be obtained with relatively small quantities, the baking industry prefers strong flavoured honeys thus maximizing flavour for the lowest possible cost. On the other hand not more than one third of the sugar in a baking recipe should normally be replaced by honey.

In <u>confectionerv</u> production, honey is still included in many traditional products which are consumed locally in considerable quantities but are also exported, such as torrone from Italy, tur6n from Spain, nougat from France and halvah from Turkey and Greece. For the production of caramels (bonbons) honey is used only in very small quantities, since its hygroscopicity presents a major disadvantage: it reduces the preservation time and softens the caramels at the surface causing them to stick together. Some caramels, made with special machinery have a liquid honey core. In gelatinous or gum products, honey can be used in the same way as other flavouring agents (aromas or fruit pulp). The chocolate industry uses honey in only a few products. One Swiss chocolate in particular, in which honey is included in the form of broken nougat, can be found worldwide.

In the <u>breakfast cereal</u> industry, honey is used either in its liquid or in its dried and pulverized form, both for better flavour and increased consumer appeal. It can be mixed with cereal flakes and dried fruits or applied as a component of the sweetening and flavouring film which covers the flakes. The dryness or hardness of the cereal can be adjusted with the honey content and the degree of drying. Some cereal recipes are given in Chapter 3.

Numerous snack bars (candy bars) are marketed in which honey constitutes the binding and sweetening agent. Other ingredients of the mixtures can be dried fruits (like raisins, figs, apples, apricots, prunes, dates, pineapple, papaya, etc.), nuts and seeds (like hazelnuts, walnuts, almonds, brazil nuts, pistachios, ground nuts, cashew nuts, sesame seeds, sunflower seeds, linseeds or coconut flakes), cereals of all kinds (rolled, as flakes or in puffed form) and possibly other ingredients such as milk powder, pollen, cacao, carob and aromas. The ingredients are chopped to various sizes and mixed with the hot honey and sugar. Depending on the composition and the degree of heating of the sugars (including honey) a more or less solid product is obtained after cooling. Some can be cooled in moulds, some be cut after cooling and others, which remain soft, have to be layered between wafers or biscuits and coated with chocolate. In any case, all such products are fairly hygroscopic and need to be packed with material impermeable to moisture. A few recipes can be found in Chapter 3 and section 2.12.6.

In the wide variety of spreads for bread, there are products in which honey is either the major ingredient, such as "flavoured" honeys, or in which it only substitutes for sugar as in cream spreads and fruit preserves. Flavoured honeys are usually marketed in crystallized form as the addition of the other ingredients speeds up the crystallization anyhow. It is better to control the crystallization and mixing rather than leaving it to chance and having the other ingredients separate from the liquid honey after a short time. The ingredients are either mixed with the honey at the same time as the seed crystals or they are mixed after crystallization has been completed, to obtain a harder or softer end product respectively. For further details see recipes of creamed honey in section 2.12.2. Sun-dried or freeze-dried fruits like raisins, apricots or strawberries may be chopped and nuts and seeds may be pureed and included in the honey, as may be cacao, cream or milk powders and even butter. In some cases the product has to be stored in a refrigerator.

Separate attention needs to be devoted to honeys with added aromas or essences, be it fruit or other aromatic essences. Such practices are, or at least have been, more common in Eastern Europe where sometimes the aromas, food colouring or even medicinal drugs were fed to the bees in sugar syrup and the "honey" extracted from these colonies sold as "strawberry honey" or "mint honey", etc. However, they are not truly honey (see definition in section 2.1). To the consumer they present something very similar to natural honeys, at least in appearance. Therefore, European Union (EU) legislation does not allow commercialization of these products under the name of

honey. Adding aromas to liquid or creamed honey produced from natural sources is yet a different approach compatible with European legislation, if labelled accordingly, but of questionable consumer appeal. This honey must be labelled so it can be distinguished from unifloral honeys.

Figure 2.4: Some honey-based bakery products also showing granola (mijesli) bars.

In the preparation of <u>marmalades</u> and <u>jams</u>, honey can replace all or part of the sugars used. The fruit and honey mixture is concentrated by boiling or under vacuum (reduced pressure) until a sugar concentration of at least 63 % is reached, which is sufficient for preservation. The boiling time can be reduced by using partially sun-dried fruits. Any reduction of boiling time or temperature will improve flavour and reduce caramelization. The last two methods, boiling under reduced pressure and using sun-dried fruits, preserve the original flavours better. The use of sun-dried fruit also requires less fuel and 1e~~ expensive equipment (see section 2.12.12). For these types of

preserves a refractometer is helpful to determine the final sugar concentration. Another alternative is the preparation of "semi-preserves", i.e. those which use less sugar (honey) and boiling (30 minutes), store well in their unopened (sterilized) original containers, but once opened have to be refrigerated or consumed within a few days. The same procedures as under section 8.10.7 can be followed.

The quantity and ratio of honey and fruits varies with the fruit and the choice of preserves. Fresh fruits contain between 3 and 20% of sugar and honey contains approximately 80% thus the approximate requirements can be calculated. To obtain a suitable consistency in those preserves with a relatively low sugar content, pectin is added at a rate of 0.1 to 0.2%. Lemon juice or citric and tartaric acid may have to be added to make the mixture sufficiently acidic for the pectin to gel. For home and artisanal use of honey in marmalades, jellies and fruit syrups, there is a multitude of family recipes, but industrial use of honey in preserves remains very limited, probably because of economic considerations. A simple honey jelly made from a mixture of honey, pectin and water is presented in section 2.12.13.

In Italy, a product type with whole dried fruits or nuts in honey, or honey with dried fruits and nuts, is quite popular (see Figure *2.5).* Clear jars, preferably glass, are partially filled with low moisture, slow crystallizing, light coloured honey and then filled with dried fruits or nuts. If dried fruits with a relatively high water content like pineapple, chestnut, apricots and figs are added, fermentation may occur and the final moisture content of such honeys has to be closely observed or the honey be replaced (see section 2.12.8).

Figure 2.5 : Hazel nuts packed in liquid honey.

The use of honey mixed with milk or milk products is a very common home remedy against colds and infections of the throat. In the industrial sector some non-medicinal honey-milk products exist, such as pasteurized and homogenized milk sweetened with honey for long-term storage. One particular honey-milk is prepared with dried

milk powder plus 25 % honey and 10% glucose (Spo~ttel, *1950).* Another product is yoghurt with honey (Spanish Dairy Corp., *1975).* In South America dulce de leche (sweet milk) is almost as essential to the Argentinean diet as meat, and is an extremely popular spread. Though mostly prepared with other sugars, honey makes for a much richer flavour (see section 2.12.7). In yoghurt, honey is used as a sweetener or like other flavourings and is mixed at the rate of 10 to 15 % either before or after fermentation. Alternatively, it may be left separately at the bottom of the container. The mixing causes a slight loss of viscosity of the yoghurt, which can be corrected by adding skimmed milk solids (Brown and Kosikowski, 1970). One of the Italian industry leaders in this sector produces a yoghurt with orange blossom honey, the aroma of which blends very well with the yoghurt. In special combination packages a fruit granola mix is packed above a honey-sweetened yoghurt (Colangelo, 1980).

Adding honey to <u>ice creams</u> has been suggested several times, but at least in Italy, ice creams sweetened with honey have never had much commercial success, probably due to the fact that these ice creams melt more easily and at lower temperatures than those made with sugar. This causes problems in distribution and open sales presentations together with other sugar-based ice creams. In other countries, but particularly when ice cream is sold in pre-packaged individual portions or larger 0.5 to 2 litre containers, honey-based ice creams are marketed successfully. The addition of more than 7.5 % honey softens the ice cream significantly, due to its lower freezing point.

In the industrial <u>non-alcoholic</u> <u>beverage</u> industry, the use of honey is relatively recent and is expanding. The reasons can be found in a wider distribution of "functional" drinks such as health orientated, strengthening or replenishing isotonic drinks. Honey drinks are most frequently mixed with lemon juice for a pleasant sweet and sour taste, but other fruit flavourings such as apple juice are often added. In 1990, over 40 new honey drinks were introduced in Japan, of which one (on a honey and lemon juice base) was introduced by the Coca-Cola Bottling Co. of Tokyo (PRC, 1990). In many fruit juices too, honey is added as a flavouring and sweetener. In apple juice it is also used to clarify the fresh juice (Lee and Kime, 1984) by adding 4% of a solution containing equal proportions of honey and water (Wakayama and Lee, 1987). Ice tea can be flavoured and clarified with the addition of honey and lemon juice.

These new beverages take advantage of a special ultrafiltration process. This filtration through special membranes eliminates any impurities, microscopic granules (pollen) microorganisms and even macromolecules such as proteins, which might otherwise produce turbidity or flocculation in clear beverages. Such ultrafiltered honey loses some of its flavour and colour but gains in consistency, which is highly appreciated by food processors for its lower production cost. This ultrafiltration may soon find wider application not only in the beverage industry, but also in the dairy, cosmetic and pharmaceutical industries (Lagrange, 1991).

For inclusion in some recipes, honey is also dried or dehydrated by various industrial techniques (Olstrom, 1983), usually some type of vacuum or spray drying. However, dried honey is even more hygroscopic and needs to be stabilized by mixing with other powders such as starches, flours or other non-hygroscopic sugars, which are compatible with the final recipe. The percentage of stabilizers is in general around 55 % but may vary from 20 to 70% in case of, for example, porous maltitol powder (Ebisu et al., 1988). The powdered honey is used in dry mixes for cakes, breads and drinks or energy health powders and avoids the need to handle any liquid or sticky honey. Other applications are in cosmetics and alcoholic beverages, where additional water content is not desired or where handling of liquids increases production cost. Lupke (1980) discusses the use of dried honey in baked goods in Germany. Yener et al. (1987) describes different production techniques used in Turkey for the stabilized dry honey powder. Crane (1990) reports granular dried honey as reducing shrinkage of meat products by 19% and production of an additive-free dried honey powder has been mentioned in the Speedy Bee (1988).

Honey is also used in the manufacturing of sauces, the preparation of canned meat and honey cured (cooked) hams. Distilled alcoholic beverages incorporate honey as a flavouring agent after distillation, as for example Benedictine in France, Drambuie in Scotland, Irish Mist in Ireland, Grappa al Miele in Italy, Krupnik in Poland, Barenfang in Germany and many others.

For all the mentioned preparations, most of all for those with a high honey content, the quality and flavour of that honey are important. Any recipe will have to be adapted to the type of honey available and most of all to its water content, which determines the cooking or baking times in pastries and preserves, and the appearance, consistency and stability of other products.

2.5.3 As an ingredient in medicine-like products

The medicinal use of honey is probably its most widely known use, but such uses do not require special preparations. If not used straight, it is mixed at home with other liquids such as hot milk, teas or other infusions, wine and other alcoholic beverages. The pharmacopoeias of many countries describe a honey-based preparation which can be prepared by pharmacists (honey rose water) which is used for topical application in infected throats and various ulcers of the mouth (see 2.12.15).

More common is the use of honey in herbal and other traditional extracts. If the extract is presented in the form of a syrup, the preparations need to be sterilized with heat before or after the addition of the active ingredients, or a preservative like potassium sorbate or alcohol needs to be added. Sometimes fermented honey syrups are used as a base. These fermented syrups are made by adding yeasts to a mix that contains a much higher ratio of sugar to water (1:1) than is used for honey wines, mead or beer (see next section). Plant extracts are added after fermentation and clarification.

The addition of honey to herbal extracts and also prior to fermentation (as described above) is commonly practised in ayurvedic medicine as mentioned in 2.4.1. Traditional African medicinal extracts are also mixed with honey and probably not only because they are easier to take that way. In Europe, many traditional formulations are also known and some were even recommended by Hippocrates (Adams, 1939).

Honey is also a fundamental ingredient in some medicinal wines and vinegars. In one case herbs are crushed and immersed for 10 to 30 days in the wine, to which some alcohol may be added in order to improve the extraction and preservation. The liquid obtained needs to be filtered and pasteurized; honey is then added.

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2.5.4 Products of honey fermentation

In many regions honey is or was the only, or the most accessible source of fermentable sugars. In some parts of non-islamic Africa, the traditional manufacture and consumption of honey beer is still very common. The base is crudely pressed or drained honey, often with added brood or pollen. An additional nutrient base is generally provided for the yeasts, which may add characteristic flavours as well (see 2.12.5). Occasionally, other available sugars or sugar sources are added, but always the beverage is consumed before fermentation is finished. Preparation by a skilled brewer (in East Africa most commonly women) can be as fast as 5 to 6 hours. Consumption (most commonly by men) is usually still faster.

In Europe, traditional fermented honey products, some similar to African honey beers, others more refined for longer storage, have largely been abandoned and replaced with grape wines and grain beers. The fundamental problem with mead, the honey wine drinkable only after some months or years of maturation, is that without precise control of the yeasts and other microorganisms growing in the must, final flavours can often be very disappointing. The must of honey water by itself does not contain sufficient yeasts, nor the right kind of yeasts or nutrients to allow rapid fermentation. The yeasts most commonly found in honey (Zygosaccharomyces) grow only in concentrated solutions with more than *50%* sugar. Unlike honey beer production, even if sufficient yeast is added at the onset to produce rapid fermentation, the whole process lasts much longer, during which strong flavours derived from other microorganisms can develop. Probably also in order to cover unpleasant flavours, old mead recipes often prescribed the addition of fruits or aromatic herbs. The beverage is then referred to as metheglin.

New microbiological understanding of fermentation processes lead to better controlled working conditions and more reliable production. The result is better control of final flavours. As a consequence, production of meads is becoming more popular again (see 2.12.4). There have been many books and articles published describing various processes and recipes. Among them in French by Guyot (1952), in Spanish: Persano (1987) and in English: Adam (1953), Morse (1964 and 1980), Morse and Steinkraus in Crane (1975), a recently reprinted edition of Gayre (1948)

as Gayre and Papazian (1986), Berthold (1988a) and Kime et al., (1991). For those with access to international computer networks, a discussion group of mead producers has been established. Further information can be accessed through any of these many recipes and instructions will certainly help, but only personal experience and lots of patience may produce a tasty mead.

Through refermentation by careful addition of honey or incomplete primary fermentation prior to bottling, a sparkling mead can be produced. Refermentation with selected yeasts can also produce a sherry mead. In Poland, meads with extremely high sugar contents are traditionally produced from musts using equal volumes of honey and water. This "Dwojniak" has to mature for very long periods (5 to 7 years) but the primary fermentation is similar to the one mentioned earlier for medicinal syrups from plant extracts and can be conducted with the honey's own osmophilic yeasts. A must with a honey to water ratio of 1:2 requires only 3 years of aging and is prepared with a special strain of wine yeast (Malaga type). This "Trojniak" is still fairly sweet and is preferably made from cornflower (Centaurea) honey (Morse and Steinkraus, 1975).

Honey vinegar can be produced from mead in the same way as wine vinegar. Unless there is some very special appreciation of this unique flavour, the production however, is hardly feasible economically. Mead can also be used as a base from which distilled alcoholic beverages can be produced. Such production is usually for home consumption only.

Most countries permit the production of alcoholic beverages for personal consumption, but require special licenses for commercial production and sale. Equally, there may be restrictions on the use of certain additives and of course, there are countries in which alcohol production, sale and consumption are not allowed at all. Therefore it is necessary to first inform oneself about the local regulations and proceed from there. A few detailed recipes can be found in the recipe section (2.12.4).

2.5.5 Others

The tobacco industry is estimated to use more than 2000 tons of honey annually to improve and preserve

tobacco's aroma and humidity (Nahmias, 1981). Since tobaccos, at least in part, are valued according to the rate at which they dry, the importance of honey for the more valuable tobaccos can easily be understood.

Wax moth larval diets sometimes contain honey to improve survival rates (Eischen and Dietz, 1990). These larvae are raised for scientific experiments and fish bait and could be used as human food as well. Diet descriptions and raising instructions are given in section 8.10.11.

Honey is also mixed in solutions with other substances to attract insects for pollination of some agricultural crops. There is however, no scientific study which shows that such treatment increases pollination significantly.

Nahmias (1981) mentions the use of honey for treating meat packing paper in the USA and coating coffee beans prior to roasting in order to increase the aroma of each product.

The cosmetic industry uses honey as a skin moisturizer, softener and restorer of the skin's own moisturising factors in creams, soaps, shampoos and lipsticks. Because of its stickiness it can however only be employed in small quantities. Further details can be found in Chapter 9.

2.6 Honey harvesting and processing

High colony yields are only possible with well populated colonies in areas with abundant nectariferous flora. The honey needs to be harvested before the bees can consume it for further colony development, but sufficient quantities have to be left to provide for the basic needs of the colony. The different management techniques to provide the above conditions depend on the local conditions and cannot be the subject of this chapter, but are found in regular beekeeping textbooks. However, the different management and harvesting techniques can influence the final quality of the honey (Krell et al., 1988).

The following discussion on honey harvesting and processing is intended for both the honey buyer as well as the producer in order to clarify the necessary precautions to be taken to assure a high quality primary product. Only if

the raw material is of good quality can the end product be of good quality.

2.6.1 Colonv management

The exploitation of honeybees by man is basically aimed at the harvest of honey. The most rudimentary and ancient method, still employed in some parts of the world, consists of collecting honey from wild swarms. Usually, no attention is paid to the survival of the robbed colony. Combs with honey, but also with brood and pollen are either consumed directly, without any transformation, or used in the production of fermented drinks. Honey from this kind of harvesting is most frequently mixed with pollen and brood juice and all other parts of the hive. While nutritious, it is not a product that can be included in processing of value added products, other than the production of locally appreciated fermented drinks.

The next step in the technological evolution of beekeeping is the keeping of bees in "traditional" hives, made of any kind of suitable, locally available material: tree trunks, rock caves, bark, straw or other plant materials, mud, dung, clay, cut timber or even special cavities provided in stone or mud walls. Harvest time is when the colony has stored the maximum amount of honey. Different degrees of care as to the survival of the colony, are used during harvest, depending on the type and abundance of the bees and the knowledge of the beekeeper. Sometimes, more refined techniques are employed, such as dividing colonies or moving hives according to nectar flows. Thus production becomes more reliable, still involves little expense, but nevertheless remains relatively low in volume. Honey produced from this type of beekeeping can be of good quality depending on the knowledge and care taken by the beekeeper. Product quality ranges from that of the most negligent honey robber to that of a quality conscious, topbar hive producer.

A further evolutionary step is represented by the use of hives with moveable combs, but without frames or foundation sheets. Examples are the topbar hives of Africa now used worldwide and the antique "anastomo cofini" topbar reversed skep hives of Greece. This type of beekeeping unites low cost materials and traditional practices with some of the advantages of frame hive beekeeping, i.e. the possibility to inspect and manipulate the hive and therefore to progress to a more intensive hive management. Honey is extracted mostly by pressing,

sometimes by dripping, but also by melting combs in order to separate wax from honey. This last method is not recommended because the overheating and mixture with old combs spoils the quality of the honey. Pressing (see Figure 2.6 and 2.9) and dripping can produce good quality honeys, but even with good comb selection they still contain large amounts of pollen. This by itself is no problem - on the contrary it is more nutritious - but many markets prefer a clear, non-opaque honey.

The more intensive beekeeping practices of the last century were based on the moveable frame hives and virtually all the honey on the international market still comes from this type of beekeeping. All common management practices are aimed at increasing honey yield, either directly through colony migration, adding honey supers and harvesting, or indirectly, by stimulating early colony growth, swarm control, feeding during off-season and pest and disease control. Higher productivity, when compared to well managed topbar hives however, only results from the reusability of the combs and the possibility of migratory beekeeping due to better comb stability. Centrifugal extraction allows quick processing of large quantities and produces honey with the least amount of contamination by other hive materials. The handling of large quantities allows other processing technologies which foster the production of a uniform product with high control of quality standards.

2.6.2 Unifloral honeys

Unifloral honeys represent a sizeable and well-paid portion of the European honey market. Their production depends on management through site selection and selective harvesting. Increasing consumer knowledge and appreciation of honey is developing a particular market niche for honey identifiable by a characteristic colour and flavour, and originating from one or few sources of flowers (see Figure 2.2).

Figure 2.6 : Honey presses in the foreground and water jacketed settling tanks in the background at the honey processing centre of Northwestern Bee Products, Kabompo, Zambia, which buys, processes and exports honey and wax from mostly traditional barkhive beekeeping.

Differential pricing sometimes makes the production from rarer floral sources very attractive. Even in some developing countries, honeys from certain areas are preferred, though not always directly for reasons of floral origin, but sometimes for quality, liquidity, colour or simply because it looks and tastes the way the most commonly available honey tastes.

The techniques to produce unifloral honeys are based on the possibility of separating honey of one floral period

from earlier and later nectar flows on an economically interesting scale. The most commonly used technique is based on migratory beekeeping. Timing the relocation of apiaries, as well as the placing and removing of supers, is of greatest importance. Care also needs to be taken that honey already present in the colony cannot contaminate the colour or flavour of the unifloral harvest. Even if the production of unifloral honeys is not possible or economically feasible, the organoleptic characteristics of the honey (appearance, colour, flavour and taste) are still the elements that more than anything else contribute to its consumer appeal. It is therefore always a good practice whenever possible to avoid harvests that are not much appreciated, i.e. move bees to other areas or leave bitter or otherwise unfavourable honeys to the bees and harvest only at other times of the year.

2.6.3 Contamination during production

The location of colonies in industrial zones or other areas with considerable air pollution such as cities, can lead to considerable contamination of the various hive products with noxious or toxic chemicals. In Canada, USA, UK and Italy, honeybees were used to monitor environmental pollution, since accumulations of certain metals and other substances could be measured in hive products, mostly in pollen but also in honey (Meyer, 1977; Tong et al., 1979; Bromenshenk et al., 1985 and Accorti, 1992). Agricultural use of toxic chemicals is another common and very likely source of contamination. Crane (1990) gives a list of pesticides found in contaminated honey and the quantities in which they are commonly found. Their overall presence is low in regard to permissable limits in fruits for example, but nevertheless, they are present.

Radioactive contamination throughout Europe after the Chernobyl nuclear reactor incident showed in nectars and honeys for a considerable time (Kaatz, 1986 and Dustmann and von der Ohe, 1988). Since most of the contamination was due to plant uptake of radioactive elements replacing normally occurring minerals, the overall content remained relatively low. Although closer to the accident scene and immediately after the incident, safety limits were exceeded. This was mostly due to short lived iodine isotopes, as for example in Austria (�sterreichischer Imkerbund, 1986).

Further contamination may result from dirty water sources and non-floral sugar sources. One very productive

location, giving several abundant harvests all year round, was, for example, very close to the centre of Georgetown, Guyana. However, it was also very close to the local soft drink factory which continuously spilled considerable amounts of sugar. Such honey was not truly honey and had a very characteristic taste.

The worldwide exchange and shipping of honeybee colonies and queens has led to the introduction of new honeybee diseases in many parts of the world. Unadapted bees cannot resist the new infections and help from the beekeeper is required. Such help usually involves chemical treatments. If unsafe chemicals are used or even if relatively safe chemicals are applied in exaggerated quantities or at inappropriate times, honey is contaminated. Problems with such contaminations have increased in recent years. Buyers are increasingly alert and test regularly for residues. Another source of contamination is the treatment of combs against wax moth during storage. All available chemical treatments leave residues in the wax and only abundant aeration (ventilation) for at least a couple of weeks can reduce the hazard. Well ventilated storage without chemicals is preferred.

2.6.4 Contamination during harvesting

Many harvesting methods are available to separate bees from their honey. Combs can be taken out one at a time and bees may be removed by shaking and brushing. Whole supers can be cleared of bees with a strong air blower. An inner cover or special board with a one-way bee escape can be placed below the honey super. Up to one deep, or two shallow supers, can thus be cleared in 24 hours, if enough space is available below. This method cannot be recommended if colonies are sitting unprotected in the sun, which might melt the combs in the now unventilated supers. None of these three methods will contaminate the harvested honey.

The use of unpleasant smelling chemicals to drive bees away is a technique preferred by many beekeepers because it is quick and easy. Some of the chemicals are illegal for use in many countries, leave unpleasant flavours and odours, are toxic and are absorbed by wax and honey, e.g. carboxylic acid, benzaldehyde, nitrobenzene and others (Daharu and Sporns, 1984). Careful use of butyric acid, marketed as "Bee-go" in the USA has so far not been proven to produce any contamination, but in general, the use of chemicals during harvesting cannot be recommended.

Excessive use of smoke during harvesting will flavour the honey quickly, no matter which smoker fuel has been selected (see Figure 2.7). Microscopic contamination with soot can also be detected. No chemicals should be included in the smoke. Though unavoidable with some bees, heavy use of smoke can be reduced by selecting more favourable (but perhaps more inconvenient) harvesting times (weather, time of day) and shorter and more frequent harvests. A summary of various production features influencing honey quality is presented in Table 2.9.

Figure 2.7 : Heavy smoking during harvesting will flavour the honey.

2.6.5 Cleanliness

Honey in combs, be it in supers of frame hive beekeeping or in the broken combs from topbar or traditional fixed

comb beekeeping, already needs to be regarded as a food product. From a microbiological point of view, mature honey is a very stable product, which is neither altered by, nor, does it permit the multiplication of bacterial or fungal organisms. It can nevertheless be contaminated by either non-biological substances or by potential human pathogens. Every caution and care in hygiene should therefore be taken to prevent any form of contamination.

This general requirement must be taken into account during all processing phases. Already in the comb, contrary to many beekeepers' beliefs, honey is exposed to the danger of contamination, since the surface area of contact with the environment is very large. Contact with humid air (during days between harvesting and extraction), with the soil (supers set on the ground, truck bed, honey house floor or combs and frames dropped on the ground), unprotected transportation on dirt roads or in dirty buckets without a lid during comb harvesting and exposure to insects and other animals, can adversely affect honey quality (see Figure 2.8).

Table 2.9:
Beekeeping methods which may have negative effects on the quality of the honey

Beekeeping method	Possible damage to honey
Location of hives in densely urbanized or industrialized zones or areas otherwise subjected to strong environmental pollution, including agricultural pesticide use	Contamination of honey with noxious or toxic residues, possibly damaging to human health, or with sugars not of nectar or honey dew origin
Inappropriate use of antibiotics and other drugs or chemicals to	Contamination of honey with the same substances

treat or prevent honeybee diseases or control pests	
Use of organic chemicals like naphthalene, ethylene dibromide or paradichlorobenzol for comb protection during storage and treatment against wax moths	Contamination of honey with the same substances
Use of chemical repellents during honey harvesting	Contamination of honey with the same substances
Inadequate use of smoke by quantity or type of combustion matieral	Smoky odour and other flavours of honey and contamination with microscopic soot
Use of old and dark combs and/or brood combs	Honey of darker colour, comb odour, higher acidity and faster aging
Use of combs with residual honey from a previous year	Honey high in yeasts and possibly faster fermentation; premature crystallization of susceptible liquid honeys; contamination of unifloral honeys
Harvesting of incompletely	Excessive moisture content in

sealed combs, particularly during the nectar flow	honey

The extraction room or space needs to be exceedingly clean as well as the space where the honey supers or combs are stored prior to processing. If processed outside, processing should not be done during a windy or rainy day. All surfaces, hands and containers coming into contact with the honey need to be particularly clean. The need for clean water may influence the site of processing centres or the feasibility of beekeeping in certain areas. In many countries there are explicit rules to which any honey producer has to adhere, as far as minimum facilities and cleanliness in the extracting room are concerned.

Figure 2.8 : Honey comb cropping in traditional or topbar hive beekeeping should only be done in buckets with well sealing lids. The same type of buckets are necessary for storage of extracted honey.

Among developing countries, Trinidad and Tobago is an excellent example for such rules and the compliance of beekeepers to these standards (see Annex 2 for contact address).

Containers and processing equipment need to be made of material compatible with this very acidic food. No copper, iron, steel or zinc should be used as they dissolve into the honey and may affect colour and flavour, and might reach toxic levels. If further processed into other products, chemical reactions of the contaminants with other ingredients might cause strange discolorations and off-flavours. Instead, stainless steel, glass and food grade plastic can be recommended. Galvanized steel (zinc) may be used for surfaces which come into contact with honey only for short periods, such as in extractors. Used containers need to be free of any odours since honey will absorb these very quickly. Storage containers made of improper material can be coated completely with beeswax or food grade plastic liners to avoid any direct contact. There is, however, no adequate protection if the containers have been used previously for toxic chemicals.

2.6.6 Processing

Uncapping is the first real step of honey processing. It consists of the removal of the thin wax layer that seals the honey cells. The wax caps can be sliced off with a sharp, thin, long knife or special knives heated by steam or electricity. Large numbers of frames are more rapidly processed with partially or completely automated uncapping machines which cut or chop the wax caps with blades, chains or wires.

In comb harvesting the equivalent step is the comb selection (eliminating pieces of comb with pollen or even brood - something that should already have been done during harvesting) the removal of bees etc. and the subsequent thorough mashing of combs. Processing proceeds further by either letting this wax and honey mixture separate by dripping through a screen (strainer) or by pressing it in special honey presses (see Figure 2.9). Modified centrifugal extractors (see Figure 2.10) can also be used (Krell, 1991).

Honey frame processing proceeds, after uncapping, to centrifugal extraction. Extractors range in size from a

manual 2-frame model to motorized units extracting more than 12 deep supers at a time. More commonly, 24 to 72-frame radial extractors are used for commercial enterprises. The smaller units for part-time beekeepers can be made out of recycled materials (see Figure 2.10). Though honey can be extracted faster and more completely at higher temperatures, the combs will become softer and might break. Therefore, extraction temperatures should not exceed 30^{0}C.

2.6.7 Purification

The next step is the removal of any impurities such as wax particles, other debris and air bubbles incorporated during extraction. There are two practical techniques: settling and straining. The first simply consists of leaving the honey in a suitably large container, so that impurities can separate according to their specific weight, i.e. air bubbles, wax particles, insect pieces and other organic debris float to the surface while mineral and metallic particles drop to the bottom. The surface scum can be removed carefully, or honey can be drawn off near the bottom for bottling without disturbing either surface scum or bottom sediment. Settling velocity varies with particle size (the smallest settle the slowest), container size and honey viscosity, i.e. moisture content and temperature.

At temperatures of 25-30^{0}C settling is generally rather quick and can be completed in a few days. Tanks have to be well covered to avoid excessive contact with air. The process can be accelerated by letting honey flow through special buffer tanks prior to filling into the settling tanks. In these buffer tanks the honey is heated through a water jacket, similar to a water bath and then forced to flow up and down through several compartments in the process of which impurities remain at the surface Such a device works well with medium quantities and once heated like this, the honey can also be filtered more easily.

a) **b)**

Figure 2.9: a) Small, common honey press in Zambia;
b) Larger honey press used to squeeze honey from cappings in Italy.

Subsequent settling frees honey of air and foam and, if containers are big enough, allows some mixing of extractions from various colonies, i.e. blending to achieve a certain degree of uniformity of the end-product. The disadvantage is the cost of the containers for the extra storage lasting several days, which in large operations requires several very large tanks and large amounts of extra space.

Straining can be used instead of, or in addition to, settling. It is more frequently used in larger processing plants, where many tonnes of honey are processed every day and where it is therefore inconvenient and uneconomic to immobilize honey for as long as is required for settling.

Strainers can be simple metallic screens, preferably covered with a fine nylon mesh (fine nylon stockings are the best) or a nylon sack filter submerged in a tall, narrow tank. The sack-like filter can also be made of several layers of increasingly finer metal screens (perforated metal sheets). These filters have the advantage of a large filter surface which can be submerged to avoid any further inclusion of air. The finest mesh size used commonly has holes of 0.1 - 0.2 mm diameter. The temperature, for this kind of straining, must be near 30�C.

Finer filtering is usually only done in association with pasteurization and heating of honey to 77 -78�C (see 2.12.1). It serves the purpose of removing all fine materials, including pollen, in order to delay crystallization for as long as possible. Such filtration requires high pressure filters with diatomaceous earth. Since it requires heating, and particularly because it removes some natural ingredients such as pollen, this honey cannot be sold as table grade honey in EEC countries. Consumers in some countries regard it as inferior in quality, while it is the preferred quality for supermarkets and other large marketing chains which want a product with a long shelf-life in a homogeneous liquid state.

a)

d)

b)

c)

e)

Figure 2.10: Manual 4 frame radial (medium size super frames), 4 frame tangential (2 deep and 2 medium size super frames) and comb honey extractor all in one made from construction steel, bicycle parts, 110 litre plastic drum and 5-mesh galvanized screen. This is a beekeeper's design (Mr Beizel, Formosa, Argentina) adopted and modified during an FAO sponsored beekeeping project *TCP/ARG/0051.*

a) View of top of extractor with basket modified for six shallow super frames or 2 deep super frames.

Ideally, the gear and chain assemblage should have a plate below it to protect the honey from oil or other debris. The whole assembly can be easily removed for cleaning or use of the drum for storage.
b) Bottom of wire basket with support for radial extraction, covered with aluminum (or wood) plate for broken comb extraction.
c) A 4-frame (8-shallow) tangential extractor modified for radial 4-frame and broken comb extraction.
d) A normal tangiential extractor similar to
e) modified for broken comb extraction with solid bottom plate and a finer mesh screen (5-mesh) at the bottom 15-20 cm. e) A large honey press/extractor for separating honey from comb uncappings used in Italy.

All the above purification methods can only be applied to liquid honeys. It is therefore preferable to use them immediately after extraction, when honey is still naturally liquid and at the right temperature. In processing plants of large buyers, it is however often necessary to purify honeys that have already crystallized. In this case, the honey has to be melted first without destroying any of its characteristics (see 2.12.1).

Even the small buyer sometimes has to clean purchased honey, since most beekeepers do not process their honey to sufficient standards for inclusion in other products and often not even well enough for bottling for direct retail sale. Here too, it is important to proceed as soon as possible after purchase, before crystallization commences. On a small to medium scale, settling is usually the least expensive and least labour-intensive method, particularly if the honey barrels can be stored for a few days in a warm (30 – 35�C) room. As with larger buyers, additional straining assures that the raw product offers at least a minimum standard of hygiene requirements.

Extracted, cleaned or purified honey is ready to be consumed directly or to be included into other products. But processing technology does not end here Other techniques are employed to prepare a product of uniform, constant and agreeable appearance, or to prevent the only possible storage problem: fermentation.

2.6.8 Moisture content

Moisture content of honey is practically the most important quality parameter, since it affects storage life and processing characteristics Even though moisture can be removed after extraction, only completely ripe honey should be harvested, i.e. combs with more than 75 % of the honey cells sealed. To achieve such results prior to the very end of the nectar flow, the colony has to have sufficient super space for storing incoming and ripening honey. When the average atmospheric humidity is not much above 60%, a moisture content below 18% may be expected in the honey (see Figure 2.5). In more humid climates even sealed cells can contain honey with more than 24% even 28% moisture content (Krell, unpublished, and Crane, 1990, respectively). Combs containing fresh nectar should never be harvested, because it can dilute and spoil the whole harvest - unless of course the purpose of harvesting the honey is making beer.

Post-harvest reduction of moisture content can be achieved by leaving honey supers in warm rooms at 30 to 35 ^{0}C and circulating warm air through them. At this time, the surface area of the comb relative to the honey mass is still fairly large and does not require any extra equipment for efficient evaporation. In relatively cool climates the circulation of air heated to 35 ^{0}C can reduce moisture content in open honey cells by 1 to 3 %. This is the easiest and cheapest of all post-harvest moisture controls. The relative humidity of the air at 35 C has to be controlled, however. If it is more than 60%, aerial moisture will have to be removed by a dehumidifier. In tropical climates, the air temperature will have to be considerably higher (damaging to honey) or prior dehumidification of the air will be necessary. This requires a small, specially sealed room and a dehumidifier.

Post-extraction moisture removal is slightly more involved (Alfa-Laval, 1988), but small scale methods are available (Maxwell, 1987 and Platt and Ellis, 1985). Krell (1992) described a cheap small scale honey drier, adaptable also for solar heating, in which hot air is conducted over a thin film of honey running on an inclined surface. Large scale solar or semi-solar models have been tried successfully (Paysen, 1987). In industrial plants, vacuum driers are used at less than 45 ^{0}C, similar to those for dehydrating fruit juices and other foods, but smaller vacuum driers especially made for honey drying are available for less than US$10,000 (see Figure 2.11). Many other systems have been designed over the years, but honey should require such treatment only under exceptional conditions.

2.6.9 Prevention of fermentation

Fermentation is the only microbiological alteration to which honey is susceptible. Only osmophilic yeasts can grow in the high sugar concentrations, but their presence is ubiquitous in honey, nectar, hive interiors, dust and soils. Their rate of multiplication increases proportionally with increasing water content, up to a certain point. Below 18 % moisture content there is little probability of fermentation, but even at concentrations below 17.1 % the risk of fermentation cannot be completely excluded. This aspect of fermentation depends on factors such as the quantity of yeast and other growing factors - honey temperature and the distribution and availability of water following crystallization.

Appropriate and expensive cold storage (see section 2.7) but above all, careful production techniques, can prevent fermentation. If, after all precautions and care, honey cannot be harvested at less than 18% water content, excessive moisture should be removed (see section 2.6.8). Either one of the previously described methods, if carefully used and if honey has not yet fermented, can prevent fermentation without degrading the honey.

Another method is based on pasteurization and the destruction of the yeasts. The osmophilic yeasts found in honey die after only a few minutes of exposure to temperatures between 60 to 65 ^{0}C. If the honey is heated and cooled quickly enough, with special heat exchangers feasible only on an industrial scale, very little damage occurs to the honey. Often these pasteurization treatments have two functions, the prevention of fermentation and the postponement of crystallization (see section 2.12.1).

Relatively small quantities of honeys with high moisture content do not justify complicated and costly pasteurization, or drying. They should be directed towards a market with immediate consumption, for processing into other food items or for fermented drinks (see recipes in section 2.12). Such honey should not be considered for shipping over long distances as containers might explode. Careful heating in a water bath to wax melting temperatures (about 65 ^{0}C) and subsequent cooling in a water bath with running water may prolong storage life. For small quantities, this is an acceptable compromise between spoilage by fermentation and some loss of quality by heating. Under most circumstances, however, water baths are overheated and honeys are not properly stirred

and cooled down rapidly enough. Pasteurization on a small scale can therefore only be recommended for emergencies and not as a routine procedure as it is used in many places. The pasteurized honey needs to be bottled hot in a clean environment in order to prevent reinfection with omnipresent yeasts.

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2.6.10 Heating

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As can be understood from the previous discussions on viscosity, fermentation and moisture control and as will be seen in the following sections, heating of honey makes production easier in many ways. Simultaneously however, any application of heat has a negative effect on honey through the loss of thermolabile, aromatic substances, which is proportional to the temperature and duration of heating (see also section 2.7.). The basic concept therefore is to heat the honey only to the lowest temperature and for the shortest period consistent with the desired technical objective.

Honey owes its distinctive characteristics not to the stable major compounds which can be found in any other sweet product such as sugar, molasses, syrup and marmalade, but to the multitude of minor components originating from the nectar and the bees themselves. Many of these substances which give honey its specific aroma, flavour and some of the biological activities are unstable over time and thermolabile, i.e. they are destroyed by heat. This uniqueness and fragility affords honey its legal protection and consumer preference, at least in most of Europe. All the following precautions in regard to heating, storage and further processing are made in consideration of these fundamental quality characteristics of honey

Figure 2.11 : Small to medium-scale vacuum drier for removing moisture from already extracted honey (courtesy of Dadant and Sons, Inc.).

With respect for the just-mentioned effect on its quality and its peculiar physical characteristics, honey needs to be heated always with particular care. Its low thermal conductivity makes uniform heating throughout a large body of honey very difficult and the use of high temperature heat sources like open flames or a boiling water bath may quickly lead to local overheating. This may cause significant alterations of the honey's characteristics, even caramelization. When heating in industrial plants is required in order to reduce honey viscosity or melt crystals, special large surface heat exchange systems are used with a heat source only a few degrees above the temperature to which the honey is to be heated.

For the melting of crystallized honeys in large containers, thermoregulated rooms or water baths are maintained at temperatures between 35 and 50� C. Some melting times for different size containers and temperatures are given in Table 2.10, but times also depend on the type of honey. For heating smaller quantities, only indirect

heating through the water bath method should be used (see Figure 2.12) and the water should never be more than 5-10� C hotter than the desired temperature of the honey. It should certainly never be boiling. Appropriate cooling has to be provided afterwards, like running water through the water bath.

Figure 2.12 : Small-scale heating of honey in a water bath. The inside pot should not touch the bottom of the larger, water-filled pot. Wood blocks or stones may be used to support it.

In large containers heating can be provided externally or internally with special heating coils through which hot water is circulated. Usually, some kind of mixing device like propellers, blades or recirculating pumps are added in order to facilitate heat exchange. In fact, in large processing plants, smaller containers are preheated in warm rooms kept at 6O~7O0. As soon as the honey softens at *35* to 40^{0}C, it drips out of the inverted containers over grids or inclined surfaces kept at *35 - 45* ^{0}C. Before reaching the high room temperature it is then pumped out of

the hot room into large melting vats where the melting of crystals is completed.

For smaller operations thermostatic electric heater bands are wrapped around the honey containers. Alternatively, electrically heated or hot water coils of a size adapted to the container, are set on top of the crystallized honey, slowly sinking under their own weight through the softening honey. Solar heating could be used to preheat or soften the honey to speed up the process. Even the water for the heating coils can be inexpensively heated by solar energy, since only relatively low temperatures are required.

Table 2.10:
Time required on hot rooms for melting a finely crystallized honey (17.5% water content) in a hot room without stirring, according to container size and room temperature (Jeanne, 1985)

Container size	**40�C**	**45�C**	**50�C**
20 kg	24 hrs	18 hrs	16 hrs
50 kg	48 hrs	36 hrs	24 hrs
80 kg	108 hrs	72 hrs	60 hrs
300 kg	-	108 hrs	72 hrs

2.6.11 Packaging

The bottle or package should be leakproof and airtight so as to safely contain the product, but also present the product in an attractive form, enticing the consumer to buy it. The label, container shape and material or other

packaging material should be chosen accordingly.

Labels also have to provide all legally required information and preferably a lot number to help the producer track down any problems. For discussion of special labels, packages and label printing, etc., see also section 9.9. All confections, independent of size, have to be labelled correctly, according to local laws. In addition to the legally required information, some information may be provided to the consumer on the various uses of the particular product. Though packaging does not improve the product itself, it may very well add value to the product. One such value added form consists of packaging small portions for hotels and airlines or of special gift packages with honeys of different colours and origin, or of special containers such as clay pottery (see Figure 2.13). Single portions may be packed in plastic straws (see Honeystix in Annex 2), flexible plastic bags, aluminum and plastic envelopes or inside soft plastic in the shape of animals. Multi-dose soft tubes can be sold singly or in small packages as snacks which may be carried safely to work or school, picnics, or while jogging.

a)

b)

Figure 2.13: a) A few small honey packages for tourists or hotels, restaurants and airlines. b) A display of various decorative honey containers and dispensers.

For most retailing of pure honey, the preferred packing material is glass followed by plastic or, for large quantities, metal containers coated with materials appropriate for contact with acidic food. In any case, the containers have to have a secure airtight lid. Screw top lids on glass jars are the most secure. Heat-sealed plastic and aluminum lids on plastic cups are fairly safe as well. Though not as appealing as clear glass jars, transparent or semitransparent plastic containers in stackable cup or jar form are cheaper and easier to ship and store. Screw top lids on plastic jars often leak during transport and result in sticky containers, honey loss and spoilage. A more rigid container and heat-sealed inner lids or plastic films, as used on many medicine bottles could solve this problem. Waxed cartons have been abandoned because they were not safe enough. Half and one-litre flexible polyethylene bags have been used in several countries for many years. These are extremely economic to ship, but require that the consumer has a special outer container suitable for holding the honey or the honey bag.

Recycled glass bottles may be appropriate if they can be cleaned adequately and a cork-type seal can be provided. Bottles which previously contained any oils, household cleaners, gasoline or any other non-food or non-drinkable liquid should never be used. If bottles are cleaned with soap they have to be rinsed many times. If water is limited, the bottles should be washed with sand and clean water without soap. Most screw tops for bottles do not close very well and ants frequently enter such bottles. Leaving wax and other hive debris in the honey to form a plug in the bottle neck appears to protect honey from aerial moisture and in some cases might even retard fermentation. It is however, not a form presentable to most urban consumers. Corks or wooden taps which do not seal hermetically need to be sealed with hot beeswax.

Different honey-containing products require their own specific packaging, most of which is discussed together with the products. Package choice should however also consider recyclability, disposability and environmentally friendly manufacturing of the packing materials. Excessive packaging in many countries is not only wasteful, it also contributes to pollution and waste disposal problems.

The decision about which form of presentation or packaging to choose for marketing should take into consideration the predominant local form of use, the honey characteristics (such as crystallization, fermentation and colour) the volume, the length of time between processing, retailing and consumption, the availability and cost of filling technologies and packaging materials, the potential appeal to the consumers and the environmental compatibility of materials.

2.7 Storage

Storage containers for liquid or crystallized honey should be made either of glass or stainless steel or coated with food approved plastic, paint or beeswax. Nothing should be allowed to impart any odour to the honey. Particularly if used containers are recycled, care must be taken that they are absolutely clean and have not the slightest residual odour. Honey readily absorbs odours of all kinds and these can, for example, be readily absorbed by a beeswax coating and then passed into the honey. Containers previously used for toxic chemicals, oils or

petroleum products should never be used for storing any bee products, even after coating with paint, plastic or beeswax.

Openings in wholesale containers have to be big enough to facilitate removal even of crystallized honey. To keep moisture out, lids have to be airtight and all products should be kept away from heat and (preferably) light. Also, most products containing honey should be protected from excessive moisture by special packaging: baked products in moisture proof clear plastic bags, caramels in separate plastic or waxed paper wraps and single portions of liquid or pulverized product in laminated foil envelopes made of aluminum foil covered with plastic or plastic and paper envelopes. Storage rooms should have a temperature near 20^{0}C and a relative humidity of less than *65* %. Storage of honey at more than 25 ^{0}C causes increasing quality loss with time, due to progressive chemical and enzymatic changes.

Honey is considered a stable product, in the sense that it is not spoiled by the bacteria and fungi normally responsible for food spoilage. Products containing honey however, are preferred targets for such organisms and therefore demand pasteurization (stabilization with heat) or chemical preservatives (according to product requirements) plus adequate storage and protection from recontamination after production. Proper storage and packaging together with quick marketing and consumption will reduce or eliminate the need for preservatives.

Fermentation remains the major threat to unprocessed honey, whether it is liquid or crystallized. The prevention of fermentation has already been discussed in section 2.6.9. Therefore storage conditions have to prevent fermentation through either low temperature storage or by preventing further absorption of moisture.

Even honeys which are not susceptible to deterioration by yeasts however, can be subject to other progressive alterations due to chemical and enzymatic action. These changes include organoleptic characteristics such as colour, taste and aroma, together with a loss of biologically active substances (inactivation of enzymatic and antimicrobial activity). Substantial changes may also occur in the sugar composition with an increase of disaccharides and other complex sugars and a corresponding decrease in simple sugars. Other transformations of the initial composition include an increase of acidity and HMF content. These changes occur in all honeys, but at

different rates according to their initial composition (more moisture and a lower pH result in faster changes) and storage temperatures (higher temperatures also lead to faster change). The same changes take place even faster during (and after) the heat treatments of various processing technologies. Though damaged honey does not become dangerous to human health, it nevertheless loses some of its nutritional and organoleptic values. Therefore in almost all countries, legal limits are set for the degree of "ageing" (or deterioration) of honey for food use (see quality control section 2.8).

Heat and sunlight (mostly the ultra violet (UV) spectrum) can destroy the quality of honey both in brief high exposure or in low level exposure over a long period of time. Some decay is unavoidable, but it should be kept to a minimum. UV radiation destroys glucose oxidase and thus most of the antibacterial activity. Table 2.11 lists the half-life of diastase in honey at different storage temperatures. Since it is difficult to give a precise preservation limit for honey, due to the large variability of different factors, HMF and diastase are used as indicators of damaging treatment received by a honey during either processing or storage. Decreasing half-life, i.e. faster disappearance of diastase, can therefore be equated with increasing damage to honey. However, initial diastase contents vary in different honeys and have to be known for the fresh untreated material. HMF is used more frequently as an indicator since its value is close to zero in very fresh honeys (other than a few tropical honeys) and its level increases with time and exposure to heat.

EC regulations state a minimum of 8 diastase units for honey. Thus a honey initially containing 16 units can no longer be sold as food grade honey if stored for 4 years at 20^{0}C, 18 months at 25^{0}C, 7 months at 30^{0}C, 4 months at 32^{0}C etc (see Table 2.11). In view of normal production to consumption periods, a storage temperature of 20^{0}C is considered an economical compromise. In warm climates it is important to protect storage vessels from overheating and possibly cool them by special shading or ventilation. Processing, moving and selling honey have to be as fast as possible. Care also needs to be taken that the honey is not damaged by overheating during trucking (particularly during parking in direct sunlight) or while waiting for reloading in harbours or railroad yards. The same is true for small bottles of honey sold at road sides or in market stands. They should never be left in the sun.

Table 2.11:
Diastase half-lives calculated for different storage temperatures (White et al., 1964).
(The half-life is the time in which the diastase content decreases to half its original value.)

Temperature (�C)	Honey diastase half-life
10	12,600 days (34.5 years)
20	1,480 days (4 years)
25	540 days (18 months)
30	200 days (6.6 months)
32	126 days (4.2 months)
35	78 days (2.6 months)
40	31 days
50	5.38 days
60	1.05 days
63	16.2 hours
70	5.3 hours
71	4.5 hours
80	1.2 hours

Considering the aspects of presentation of the product, maintaining its liquid or crystallized form is important (see also Figure 2.3). Only cold storage below 5^{0}C is suited to simultaneously prevent crystallization, melting of crystallized honey and fermentation. Such storage is however expensive and rarely used on a large-scale except to briefly preserve special honeys for further elaboration. Storing liquid honeys above 25 ^{0}C to prevent any crystallization can only be recommended if very quick sales are expected. A temperature of 20^{0}C was mentioned as a compromise for storage of liquid and crystallized honey. Those honey products exhibiting the same physical characteristics as natural honey need to follow the same guidelines as those for the unprocessed product. Other processed products containing honey may have individually different storage temperature requirements.

2.8 Quality control

The quality control of honey has two principle purposes. to verify its genuineness i.e. to reveal possible frauds such as artificial honeys, adulteration etc., and to determine its quality in respect to the needs of the processor and the market. The composition limits of the natural product are defined internationally by the Codex Alimentarius Commission (Codex Alimentarius, 1989 and 1994, see Annex 4) which also mentions the officially approved analytical methods. In many countries more restrictive laws and regulations exist to which one must refer if marketing in these countries is intended. Legal quality standards serve to protect the consumer, be it the processor or the end consumer.

Adulteration

In many countries it is customary to call any sweet syrup "honey". Corn, cane or rice syrup and even molasses can be seen labelled as honey. Thus it may be legal to call things honey which, according to international standards, are not. It is in the interest of the local beekeepers to have laws that define honey more precisely or at least reserve the name bee's honey for a product conforming to international standards.

Most simple adulterations of honey can be detected if certain characteristics exceed the legal quality standards, for example by a high sucrose content (> 8%) if simple cane or beet sugars are added, or high HMF values if acid hydrolysed corn syrup is used. The latter has fructose/glucose ratios similar to honey (HMF >200, White, 1980). If however, the high fructose corn syrup is used, which is produced by enzymatic processes and contains fructose/glucose ratios similar to honey, the detection of ^{13}C isotopes (White and Doner, 1978) or thin-layer chromatography (White, et al., 1979) are required. This high fructose corn syrup is not yet readily available in many developing countries, however. The isotope method can detect adulteration with any kind of cane sugar or corn syrup; even in products allegedly containing honey only as a minor ingredient (Donor et al., 1979).

Simple field methods for detection of adulteration without laboratory equipment are based on taste, viscosity (most adulterated honey is thinner, but so is honey with a high moisture content) or its solubility in cold water (see Figure 2.14). If a droplet of honey poured into cold water stays together without dissolving rapidly, it is most likely pure honey. This can be observed best against the light with a dark background. If the edges of the droplet or the thread starts dissolving during pouring, the honey is likely to have been adulterated or has a very high water content. In any case it should be kept separate from other honey until more precise tests can be carried out.

Production quality

For companies' internal quality control of production and processing different parameters may have to be taken into consideration, which depend on the requirements of the manufacturer. Internal standards serve to allow production control and product standardization, and to adjust production cost to various product requirements and different quality levels. These quality levels may be established internally, may be demanded by the market, or may be required by a company under whose label the product will be marketed. Since honey is included in a wide variety of products, these standards cannot be given here, but must be investigated through local authorities and industry organizations.

The parameters most frequently controlled by enterprises which receive honey for further processing are the condition of containers, cleanliness, the homogeneity of the shipment, organoleptic characteristics (taste and

aroma), colour, moisture content, degradation of honey measured by diastase and HMF content, composition of principal sugars and microscopic examination for the determination of botanical and geographical origin. Depending on the needs of the manufacturer, some or all of these characteristics are controlled. Large enterprises have their own laboratories while smaller manufacturers can only perform simple measurements themselves such as colour, taste and moisture determinations and have to rely on outside laboratories for more detailed analysis. Table 2.12 shows an outline of controls adopted by some European honey processors. Other parameters not mentioned in this table, such as the microbiological control of honeys destined for use in dairy products or the identification of residues of noxious contaminants such as pesticides and bee drugs are rarely controlled.

a)

b)

c) d)

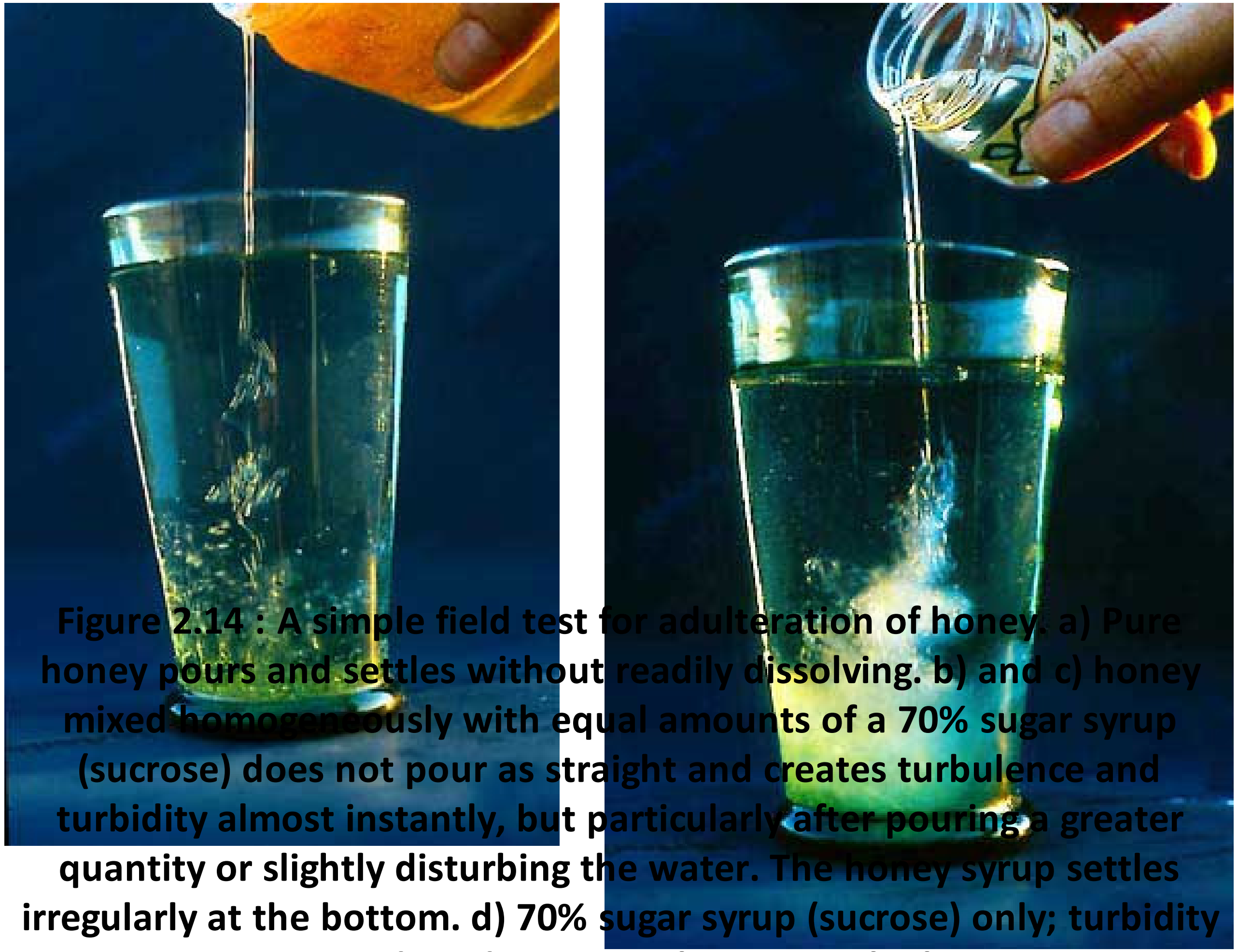

Figure 2.14 : A simple field test for adulteration of honey: a) Pure honey pours and settles without readily dissolving. b) and c) honey mixed homogeneously with equal amounts of a 70% sugar syrup (sucrose) does not pour as straight and creates turbulence and turbidity almost instantly, but particularly after pouring a greater quantity or slightly disturbing the water. The honey syrup settles irregularly at the bottom. d) 70% sugar syrup (sucrose) only; turbidity is even stronger and no distinct settlement at the bottom occurs.

Table 2.12:
Outline of quality control measures taken by a typical European honey processor on honey prior to processing

Parameters	Control method	Limits

Parameters	Control method	Limits
Containers	Direct observation	Adequate material and condition
Homogeneity of lot	Direct observation	Apparent homogeneity according to observable characteristics in whole shipment
Impurities	Direct observations of honey surface in container, filtration, or polarized light test	Presence of limited impurities such as bee and wax particles
Organoleptic characteristics	Organoleptic analysis on an average sample	Absence of defects such as strange odours and tastes, fermentation, overheating or otherwise unpleasant characteristics. Correspondence to samples from producers and to foreseen standards for end product classification

Colour	Optical comparison with Pfund meter of according to Lovibond (Gonnet, 1986a)	Correspondence to producer sample and foreseen standards for product type (Accorti et al., 1986)
Moisture content	Refractometer measurements (Codex Alimetarius, 1989)	Less than 18.0% for top grade (less than 21% max. limit)
HMF	Colorimetric method (Codex Alimentarius, 1989)	Less than 10mg/kg for top grade (40mg/kg is maximum limit)
Microscopic characteristics	Quantitative and qualitative pollen analysis (Louveaux et al., 1978)	Correspondence to declared botanical and geographic origin
Others	Official methods	According to legal limits

White et al., (1988) described relatively simple laboratory techniques and set-ups for basic quality testing of honey to determine adulteration and degeneration. Bianchi (1991, in Spanish) in an FAO bulletin describes even simpler methods. The extract of the Codex Alimentarius in Annex 4 describes the official laboratory procedures for honey quality tests.

Any control should always include verification of the proper functioning of the processing techniques and of the finished products, i.e. the consistency of characteristics important for the presentation such as colour, appearance,

physical consistency, taste and aroma. Of course, each honey containing product has its own set of production and legal quality standards which need to be observed. A sample of each processing batch should be retained under normal distribution and storage conditions, in order to monitor product shelf-life.

It is advisable that all processed products containing honey for which formulations and processes have been newly adjusted, are run through a small test (pilot production) to verify the acceptability of the product and the preservation characteristics and to reduce cost of unforeseen problems. Also in this case, the preservation of a sample of the product is good practice. Particularly during such trials and test runs, it is important to keep precise notes of all production parameters, even those that seem unimportant. This will be very helpful if some problems have to be corrected. During actual production, lot numbers on labels will be helpful in tracking down problems even if not required by law.

2.9 Caution

Honeys of some flowering species are reported in the literature as toxic (White, 1975c and Kerkvliet, 1981) because of their content of active ingredients from nectars or honeydews which are noxious or toxic to humans. Although these honeys are not very common, they can be of particular importance in some localities. The plant families and genera from which a few species have been reported to produce toxic honeys include Ericaceae (Rhododendron, Azalea, Arbutus, Andromeda, and Kalmia); Solanaceae (Datura, Hyoscyamus, and Atropa; Compositae (Senecio jacobaea or ragwort); Lagnonaceae (Gelseminum); Ranunculaceae (Aconitum), some species of the genus Euphorbia in South Africa and the honeydew of Coriaria arborea from New Zealand (Crane, 1990). Bitter and off-flavoured honeys are produced from many more species.

The consumption of honey by infants less than one year of age is not recommended by the US Food and Drug Administration (Anonymous, 1981). This recommendation is based on the correlation of some infant deaths with the ingestion of botulism spores (Clostridium botulinum) from honey. The spores were recognized in very few samples of Californian honey for the first time in 1976 (Huhtanen et al., 1981) and more recently also in the UK (Crane, 1979) and Italy (Aureli et al., 1986). Other surveys in Italy (Quagho et al., 1988), France (Cohn et al., 1986)

and Norway (Hetland, 1986) have not found any C botulinum spores in any honey samples. Though omnipresent in the environment and in many foods, the spores normally are not capable of developing in the intestines of adults or children. However, since very young infants often have less acidic digestive tracts amd less competition from a bacterial flora as yet little developed, Clostridium spores may develop in their intestines. The toxin produced by the bacteria binds irreversibly to motor nerve endings and can only be overcome by the growth of new nerve endings. Some of the typical symptoms are mild paralysis (failure to thrive), moderate to severe paralysis, which requires hospitalization, and fulminant (sudden and intense) paralysis which can lead to death without warning. Other milder symptoms can be constipation, listlessness, lethargy, diminished appetite or activity and lack of muscle control.

In the USA there have been direct correlations between honey consumption and infant botulism, but it is difficult to say whether the one third of world-wide infant botulism cases, in which infants had prior exposure to honey, were due to ingestion of spores from honey. Spores in honey cannot grow or multiply unless they have a watery, anaerobic (no oxygen) medium with a more or less neutral pH. Therefore even in the newborn infant, special conditions have to come together to allow the spores to germinate and produce their toxin, such as after changes in the intestinal flora due to antibiotics, anomalies of intestinal secretions or others. The risk for a child less than one year old contracting this infection has been estimated by Lawrence (1986) to be about 1 in 12,000. Such a risk is likely to be higher during the first one or two months and lower during the second half of the year.

In India and many other parts of the world honey is given to newborn babies during the first few days of life as a special tonic, particularly if they were born weak or prematurely (Arora and Kual, 1973; Bansal et al., 1973 and Bhandari and Patel, 1973). In countries with better infant nutrition and generally more hygienic conditions, honey may be eliminated from the diet of an unweaned child, since it is not an essential food. Under less favourable nutritional conditions the risk of ingesting C. botulinum spores through eating honey and the resulting possibility of death must be weighted against the benefit of strengthening the young organism against many other more common stresses and diseases.

Normally, C. botulinum causes problems only in badly preserved products (contaminated or insufficiently boiled

preserves or conserves, pH near 7, absence of oxygen, and storage at room temperature). Cooking the product at 80^{0}C for a few minutes will destroy the toxin and bacteria, but spores will survive up to 130^{0}C. The presence of C. botulinum in honey is not due to any carelessness or mistreatment of the honey, nor can it be eliminated with normal processing other than ultrafiltration. Conditions in properly stored honey will not allow the bacteria to grow and produce any toxin. Fortunately, it is not a risk for anybody with a healthy intestinal flora or above the age of six months or a year.

Products containing honey and intended for human consumption or cosmetics should be treated as carefully as any food item, and with even greater care as regards storage if they are prepared with no preservatives.

2.10 Market outlook

Data about world-wide honey production are published every year by FAO. In 1991, world production reached almost 1,200,000 tonnes. The increased production in the last 20 years, despite fluctuations in individual regions and countries (both industrialized and non-industrialized) is accredited to an increase in the number of hives and production per colony. The major producers are Russia, China, USA, Mexico, Argentina, Canada, Brazil and Australia. The major exporters are China, Mexico and Argentina, but the highest colony yields are recorded in Australia and Canada which have a favourable environment as well as highly developed colony management. The major consumers and importers are the industrialized countries led by Germany, Japan, USA and UK. The increased consumption over the last few years can be attributed to the general increase in living standards and a higher interest in natural and health products. Western Europe as a whole imported approximately 140,000 tonnes which is about *55 %* of consumption. The average EU per capita consumption of 600 g per year varies widely amongst individual nations, from Greece with 300 g per capita to Germany with 1,800 g per capita.

The international market usually trades honey in 300 kg metal drums and only a very small percentage of the market is traded in retail containers. The latter is mostly between neighbouring countries and within Europe, but also to the Near East and other small markets which do not justify proper bottling facilities for importers. Creamed honey from Canada is an exception with its worldwide distribution, and so is the still very limited exportation of

bottled honey from Argentina to Spain.

International prices depend, as with any other commodity, on supply and demand. During the first half of the 1970's prices increased markedly (tripling between 1970 and 1974 with increasing demand) but declined rapidly in the years immediately following. In the last 20 years however, the price has remained basically within the same range of slightly less than US$1/kg for light to extra light amber honey without any defects. Price fluctuations were influenced by market variations in producer as well as consumer nations and of course by currency fluctuations. The quality of the honey in general determines the price class, e.g. table grade (US grade A) or industrial grade (US grade C or D). Such parameters as moisture content, cleanliness, off-flavours and homogeneity are major considerations. Some importers require extra low HMF values for prime grades, but colour though not a quality, determines the final price once the minimum quality requirements within each grade are fulfilled.

In general, light-coloured honeys bring the highest price and dark ones are most frequently used for industrial production. Mild flavoured honeys are preferred, but characteristically flavoured honeys bring top prices in some countries. Large honey packers usually prefer honeys with a low tendency to crystallize. Some unifloral honeys such as Hungarian Black Locust honey bring twice the price of regular, multifloral honey. Small shipments into Switzerland of unifloral honeys such as lavender honey, in most cases already bottled, bring much higher prices. Local prices in most developing countries are higher than the international market prices and prices in neighbouring countries with less honey production or favourable exchange rates may sometimes be quite attractive.

Consumption of honey may increase further, particularly in some Asian and Latin American countries, and there is a large production potential still unexploited, but international prices are below production costs in many countries. Therefore, rationalization, product specialization and local marketing are extremely important before international markets can be approached.

Almost 20 years ago, industrial consumption of honey was only *5* to 15% of total honey consumption (UNCTADIGATT, 1977). This proportion has increased in the meantime and is expected to continue increasing,

considering the advantageous consumer appeal of products with honey as an ingredient. Unfortunately, this section of the honey market still represents the lower priced end of the spectrum, yet will require more product uniformity i.e. processing, in the future.

The retail market for honey products has very different conditions and depends much more on the economic, cultural and social conditions of each community or country. Also, a product refused in one region may still enjoy special appreciation and market value in another. This is also true for unprocessed honeys.

In countries with a well developed honey consumption, product diversity is increasing on the basis of different product qualities and characteristics. In addition to the traditional liquid and crystallized honeys of different colours, diversification based on taste and botanical or geographic origin is slowly increasing. Unifloral honeys are increasingly requested and appreciated, despite their higher prices. Multifloral honeys from certain geographic regions are also increasingly popular and appreciated by local consumers or tourists. Occasionally, some honeys become known outside their local or national markets such as Canadian clover honey in Europe or Zambian forest honey in the UK. If, for industrial use, standardization becomes more important, i.e. the same uniform characteristics in every batch, the blending of different honeys will become unavoidable. For direct marketing and for more sophisticated (appreciative) markets, the selection and distinction of particular products is the more likely and more remunerative way to achieve market expansion.

There are no separate market statistics on products containing honey or on special (unifloral or creamed) honeys. Their markets are very local, except for cosmetics, snack bars and in the future, beverages. Other exceptions may be specialized honeys like unifloral honeys, those from certain forest types or those produced in regions which are guaranteed to be uncontaminated. Occasionally other products may find a market niche among exports, but processed products for sophisticated markets face extremely high quality demands and competition.

Expansion of markets with honey-containing products should be considered on a national level or for across-the-border trade. Consumer education and of course, spending power will probably be the most important factors influencing the possibility of expanding local markets or for increased product diversity. The examples given in this

chapter might serve as ideas for possible modification and adaptation to individual circumstances.

2.11 Honey from other bees

In the foregoing pages the honey referred to was always from Apis mellifera, the European, African and Near East honeybee species which has now spread all around the world. This honey is undoubtedly the most widely collected, but regionally there are honeys made by other bee species which are sometimes collected in considerable quantities. The other Asian Apis species make a honey very similar in composition and taste to A. mellifera honey. Honeys from non-stinging social bees (Meliponini) are generally more liquid and vary widely in flavour.

Apis cerana can be raised in hives like some of the tropical A. mellifera species. It was the only manageable species in most of Asia until the introduction of European bees in many parts of Asia. Honey yields from A cerana are very small in tropical regions (3-10 kg per colony) and only slightly larger in more temperate climates (up to 25 kg per colony, with occasional exceptions). Insufficient scientific data are available to define quality standards as for A. mellifera honey. In an experimental comparison by Vorwohl (1968) ~A. cerana honey was basically distinguished from A. mellifera honey by a lower diastase and higher water content. Amino acid contents were also different and sometimes exceptionally high acidity values were recorded (Persano, personal communication). Honeys from the other two Apis species, A. dorsata and A. florea are only collected from wild colonies and less frequently from A. florea, probably because of its much smaller nest size and yield. Nothing is known about the honeys of the more recently described Asian Apis species A. andreniformis, A. laboriosa and A. koschevnikovi. These species are similar to A. florea, A. dorsata and A. cerana respectively and their honeys, collected in the same way as the ones of their "sister~' species, are therefore likely to be very similar as well.

Social, stingless bees (Meliponini) store honey in special honey pots rather than combs (see Figure 2.15). Their honey is either robbed from wild nests or, with some of the more prolific species, from specially provided nest sites (boxes). The Inca and Maya cultures of South and Central America are said to have had flourishing beekeeping activities with Meliponini species. The honeys, often very different from species to species, have a

much higher water content, are more acidic and have a stronger bacteriostatic (inhibitory) effect than A. mellifera honey and contain no diastase (Persano, personal communication; Cortopassi-Laurino and Gelli, 1991). They were locally appreciated for their therapeutic activities, similar to that of honeybee honey. Their topical use in eye cataracts and other corneal afflictions is widely known. Other insects which store sweet reserves and are occasionally robbed by man are some bumble bee (Bombus) and social wasp species (Nectarina and Polybia).

Figure 2.15: The sealed and unsealed honey and pollen pots of a stingless bee nest in South America.

2.12 Recipes

The following honey recipes have been chosen as examples of the many product possibilities in different fields. Almost all can be used as a base for numerous variations suggested by the availability of particular ingredients, by

the needs and preferences of the market, together with the distribution, taste, customs, habits, needs and economic abilities of the final customer. Other suggestions can be found in section 2.5. The suggested recipes and described uses cover several trades and industries. They therefore cannot cover in-depth all aspects, such as general, legal, technical or economical considerations, or the best manufacturing techniques of specific products. In many cases, like industrial bakery or medicinal preparations, the manufacturer has to have specific skills which cannot be transmitted in this publication. Nevertheless, those recipes that are presented should allow good quality production at least on an artisanal and small to medium scale of production. It would be appreciated by the local beekeeping industry if larger food producers could take some of the product ideas and develop their own product formulations using local beekeeping products. For any specific industrial or semi-industrial production problems or formulation possibilities, enquiries can be directed to the National Honey Board of the USA, a non-government organization financed mainly by and for the U.S. honey industry.

For practical purposes, the descriptions of processing and preparing liquid, creamed, section, comb and chunk honey are included in this recipe section. No economical consideration has influenced the choice of recipes, but solely the usefulness of the product type for artisanal, small or medium scale production.

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2.12.1 Liquid honey

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Some honeys remain in a liquid state naturally, if they have a low glucose content and a glucose to water ratio of less than 1.8 (e.g. honey from black locust, chestnut and tupelo), a high water content or if they are kept constantly at a temperature of more than 25 ^{0}C (or less than *5* ^{0}C). It must be remembered that high water content and temperatures above 25 ^{0}C are not desirable for the quality of honey.

If it is necessary to keep honey liquid for extended periods of time, some special measures have to be taken to ensure such liquidity. The following discussion is intended to give some practical hints for preventing crystallization.

In order to liquify honey which has already crystallized or has started to crystallize, the honey is most commonly heated ~ust prior to sale) to 40 - 50^{0}C until all the crystals are dissolved. The dissolution of the crystals is more commonly referred to as "melting" by beekeepers. It is more practical to melt the honey prior to bottling, but it is quicker after bottling when complete melting of all crystals is easier to control.

The length of time that honey remains liquid after such melting is variable and depends, as with unprocessed honey, on its composition and the storage temperature. Once heated honey recrystallizes, it should not be melted again, since the much larger crystals now require more heat to melt them. The degradation caused by a single treatment like this, including the damage caused by heating honey for 24 hrs at 40^{0}C and the time required to melt it completely, is far less than that produced by prolonged storage at a temperature above 25^{0}C (see Table 2.11).

For industrial processing, relatively complex techniques (not just melting the crystals) are employed to delay re-crystallization. As a first step honeys are selected and mixed in such a way that the final product shows constant colour and flavour characteristics and a relatively low glucose content. For that reason honeys with high glucose content such as rape, sunflower and composite honey are generally excluded.

The following processing method was suggested by Gonnet (1977) for honeys or honey mixtures with a glucose content of less than *35* % and a glucose to water ratio of less than 2 (see Table 2.13 for a summary of the equipment needed). Honey is partially melted in a hot room and transferred to a heated vat where it is mixed until almost all crystals have dissolved. It is then strained to eliminate contamination by foreign debris and pasteurized at 78^{0}C for *5-7* minutes using a fine-leaved heat exchanger.

Table 2.13:
Equipment of a typical processing plant for bottling liquid or crystallized honey (* with pasteurization).

Equipment	Use
Melting room	Controllable temperature at 35-50�C for warming, melting and softening of honey in barrels and jars
Pumps	Moving honey from one tank or machine to another, adapted for liquid and/or crystallized honey
Jacketed tank (#1)	receiving "dirty" honey direct from the melting room to complete melting, settling, mixing and heating
Strainer	Eliminating visible impurities
Heat exchanger (#1)*	Quickly heating honey to 65�C for honey to be recrystallized or to 78�C for liquefaction with pasteurization
Filter*	Removing all or part of the microscopic impurities
Heat exchanger (#2)*	Quickly cooling the honey
Jacketed Tank (#2)	Receiving "clean" honey, cooling it to 30�C and mixing it with seeds for controlled crystallization; mixing honey during crystallization at 20�C, or receiving honey previously cleaned and crystallized

	directly from the melting room, where it has been softened by heating to not more than 30�C.
Storage tank	Receiving warm liquid honey from the strainer or heat exchanger for bottling
Bottling machine	Bottling various size containers with liquid or crystallized honey

Together with the next step, this heating is the most important, since high temperature, besides destroying yeasts, also melts the micro-crystals responsible for starting (seeding) re-crystallization. In the next step, ultra-fine filtration under pressure, using different micropore filters or diatomaceous earth, removes very fine particles such as pollen, bacteria, etc., which might serve as seeds for restarting crystallization. Subsequently, honey passes through similar heat exchangers which cool it to bottling temperature (57^{0}C according to the American school (Townsend, 1975) -or 35 �C according to the European school (Gonnet, 1977)). It is then bottled, preferably in dry-cleaned containers. An extra step which can further prolong the liquid state is quick cooling of the bottled product and storage for *S* weeks at 0^{0}C before releasing it onto the market. After this treatment liquid storage is prolonged, but crystallisation can still occur.

This kind of filtration is a normal and accepted practice in the USA, Canada and various Latin American countries and is preferred, because in addition to a longer liquid shelf-life, it gives a clearer and brighter product. As already mentioned, in European countries such complete filtration which eliminates any microscopical particles, is forbidden. It deprives honey of valuable substances such as pollen and makes it impossible to identify its botanical and geographical origin by means of pollen analysis. It also makes impossible the identification of other microscopic elements normally found in honey. Thus honey destined to be marketed in EEC member countries cannot be filtered this way.

2.12.2 Creamed honey

As an alternative to liquid honey, techniques have been developed to guide the natural crystallization of honey towards completely crystallized, stable and homogeneous end products with a pleasant appearance, creamy consistency and good reception by most consumers. The advantage of this method is that it does not require any treatment which would alter by any means the fragile and beneficial characteristics of the honey. In addition, these methods are also well suited for small scale production and become more complicated only with an increase in quantity.

The basic principle consists of accelerating the natural tendency to crystallize by the addition of a small quantity of already crystallized honey. This method can be used with all honeys which show a tendency to crystallize either rapidly, slowly or incompletely. In the most simple method, liquid honey (naturally liquid or liquified) is mixed with completely crystallized honey, preferably containing very fine crystals, at a ratio of 9 to 1. The mixture should be warmed to only 24 to 28^{0}C in order to allow easier mixing and to ensure that none of the crystals are melting. No air bubbles should be included during this mixing. Prior to bottling, the honey is left to settle for a few hours to allow any air bubbles to escape. After bottling, the containers are kept as close to 14^{0}C as possible. Depending on the moisture content, crystallization is complete in about 10-14 days and a fine crystal honey of more or less solid consistency is obtained.

The major inconvenience of this method is the excessive hardness reached by low moisture honeys due to the formation of transversal crystals, special agglomerations. To avoid such occurrences, potentially unpleasant for the consumer, a method has to be chosen which allows the separation of each individual crystal and which thus gives the honey a creamy consistency. One aesthetic problem with this type of preparation is the formation of whitish blooms on the surface and inside enclosed air bubbles, due to the surface evaporation of water and drying of glucose crystals.

One method of softening this crystallized honey consists of two distinct phases. In the first phase the guided crystallization is conducted as described previously. However, the honey (seeded with fine crystals) is left to

crystallize for approximately 10 days in larger containers (25 to 300 kg) at a temperature of 14^0C. Instead of bottling, the containers are then placed into a warm room at 28 to 30^0C until the honey has become a little softer. During this second phase, with the honey always below its melting point, a homogenizer or mixer is introduced into the softened honey in order to break up the crystals (Gonnet, 1985 and 1986). Once stirred, it can be bottled. Alternatively, even the simple warming in the heating room and subsequent bottling will give satisfactory results, since even this small movement of the softened honey will break up the crystals. The critical point to watch is the temperature during softening and stirring, which should always remain below 28^0C. If the crystals start melting the whole process will fail.

In another method, the seeded honey is stirred at a temperature at which the crystals readily grow (near 20^0C). The same water-jacketed vats for heating honey can be used cooling with cold water. Agitation accelerates crystal formation considerably and helps formation of smaller crystals. After two to three days, crystallization is complete and honey can be bottled, possibly raising the temperature a few degrees to ease the flow.

The difficulty here is to stir a cold and therefore very viscous mass of honey. This not only requires considerable mechanical force, but also carries a risk of incorporating air and creating a foam. It is therefore necessary to work with sufficiently powerful motors and a slowly rotating propeller (a few rotations per minute) which should remain immersed in the honey. In the largest industrial operations, in addition to the standard mixing devices, a continuous cooling and scraping system is employed for homogenization. For small quantities not exceeding 100 kg at a time, it is possible to do everything manually and stir once or twice a day with a long wooden paddle.

Creamed honeys, produced by one of the last two processes, will always have a creamy consistency more or less fluid, depending on the water content. The main disadvantage of these preparations is their instability at warm temperatures. If stored at temperatures above 20 ^{0}C for many months the crystals tend to precipitate on the bottom of containers leaving a more or less thick, liquid layer at the surface. This separation of liquid and crystalline phases (or partial reliquefaction) is more rapid in honeys with a higher moisture content and at temperatures close to or above 25 �C. In temperate climates with honeys averaging less than 18% moisture and

low storage temperatures (favouring crystallization) guided crystallization appears a very advantageous and profitable process, as the profusion of the Dyce process in Canada indicates (Dyce, 1975).

A problem common to all these processes is the choice of seed honey, which has to have very fine crystals itself. Some honeys naturally form very small crystals. However, if no such honey is available, a normal, crystallized honey can be milled by passing it through a meat grinder or grinding it with a pestle and mortar to reduce the size of the crystals. If creamed honeys can be found (for example in a shop) they can be used as a starter. Small quantities are mixed with liquid honey and left to crystallize for ten days at 14^{0}C with occasional stirring. This is then used as seed for a larger batch, always mixing seed honey with liquid honey at the ratio of 1:9 i.e. 1 kg of seed honey to 9 kg of liquid honey. This process can be repeated until the final, desired batch size is reached. When bottling, sufficient crystallized honey should be retained to seed the next batch.

For the manipulation of cold and therefore very viscous honey, the mixer, pump and bottling machine have to be very strong. The facilities and structures necessary for cooling during processing and storage are expensive. Smaller scale manual operations do not have these difficulties and can produce an attractive product cheaply and without expensive equipment, if ambient temperatures are not too high. Lastly, if the honey to be processed has a high moisture content and there is a possibility of fermentation, it should be pasteurized at *65* ^{0}C for *5* to 10 minutes before crystallization. In this case, the seed honey has to be free of yeasts.

2.12.3 Comb honey

A particular type of colony management is required for honey destined to be sold in complete comb. Apart from being the most traditional form, it can also be sold to a market which rarely has access to this most basic of all bee products. Its implied guarantee of purity and freshness is appreciated by many consumers. Special production techniques have been developed to produce a clean, fresh-looking piece of section, cut-comb or chunk honey, which is easy to ship, handle and retail. In any case, these products require special care during preparation and do not favour long transportation at warm ambient temperatures, nor long-term storage.

Section comb honey is a small section of completely sealed comb built of virgin (new) beeswax, preferably with light-coloured honey which remains liquid until consumed. Round, square or hexagonal sections with prefabricated wood or plastic frames are given to the colonies with a very thin foundation sheet. The specially prepared colony fills up the sections with comb and honey which is directly packaged in an attractive clear container (plastic wrap, box with clear window etc) to protect the contents from contamination, moisture and breakage. Special frames and packaging material are sold by most beekeeping suppliers, but forms, construction and quality vary from country to country (see Figure 2.16).

Regular beekeeping texts do not always cover section comb honey production, because it requires more intensive management and better planning. A special treatment of the subject is given in a book by Morse (1978) and in the new edition of the Hive and Honeybee (Graham, 1992). Short articles, such as Taber (1991), occur occasionally in the various beekeeping journals.

For special attractions, some beekeepers have produced comb inside narrow mouthed bottles, by providing a guide and enticing bees to build comb and store honey inside the bottles themselves.

Cut comb honey can be produced in regular frames or topbar hives. If foundation sheets are used they should be particularly thin and no wires or other reinforcing materials should be incorporated into the comb. Pieces are carefully cut according to the package shape and size and are left on a wire rack to drain the honey from the cut cells, taking care to keep bees away. Once dry, they can be packaged like section comb honey in clear protective containers. Extra care needs to be taken not to break any sealed cells or smear honey over them because it will look unattractive later on. If left in the sun even momentarily, wax cappings will become transparent and the comb will break easily with the slightest movement. All other conditions, such as light-coloured honey, cold storage and avoiding rough transportation and handling are the same as for section comb honey.

Smaller comb pieces can also be packed inside jars, which may then be filled with liquid honey. Ideally the comb honey and the liquid honey will be of the same light clear colour. Each jar should have only one cleanly cut "chunk" and honey should not crystallize before consumption.

2.12.4 Mead

The quality and taste of mead depends, apart from fermentation control and the quality of the various ingredients, mostly on the characteristics and taste of the selected honey.

The first production phase consists of the preparation of the must. A good quality honey with the desired flavour should be selected and a good water supply obtained. The water can influence the mead' 5 flavour, particularly since public water supplies often have all kinds of minerals, chemicals and other ingredients" in them. Clean and soft rain or well water are best, but should be boiled first. The honey has to be dissolved in the water. larger quantities the honey should be pre-mixed in a small amount of warm water.

The quantities to be used depend on the water content of the honey and the desired sweetness and alcohol content of the mead. In general, one considers 2.3 kg of honey per 100 litres of water for each alcohol grade (% by volume) in the final product. More precisely, one has to add 21 % sugar solids (measuring only the sugar content of the honey without water) to obtain a dry mead with 12% (by volume) alcohol. Increasing the sugar solids to 25 % leads to a final alcohol content of 14-15 %. Further additions of sugar leads to residual sugar in the final product and therefore a sweeter mead.

Pasteurization is generally not necessary prior to fermentation but filtration to remove any solid particles is recommended. One school of mead makers does however recommend sterilizing or pasteurizing the must before adding the selected yeasts. This can be achieved either by heating to 78^{0}C for 7 minutes or by adding tablets that produce sulphur dioxide, as used in regular wine making. These tablets are also known as bisulphite or "Campden" tablets. The sulphur dioxide gas will escape and will not flavour the mead. These same tablets can be used to disinfect bottles, siphons, corks and funnels.

Minerals and salts are added to the cooled must as yeast nutrients (urea, ammonium phosphate, cream of tartar, tartaric and citric acids). The acids are supposed to improve the taste and prevent growth of undesirable microorganisms. Various nutrient combinations are listed in the detailed recipes below. If 50% of the water is

substituted with fruit juice, none of these additives are necessary, since the fruit juice provides both nutrients and the right yeasts. Some countries do not allow the addition of fruit juices to mead.

An adequate quantity (0.5 to 2%) of selected, active, acid resistant champagne yeasts or brewers yeasts, but not bread yeasts, are added. The choice of yeast influences the final flavour, but selection is more important in order to have complete and uninterrupted fermentation. An actively growing yeast solution should be prepared for larger batches (see second recipe below). For small batches, the yeasts can be added directly to the must.

In order to speed up the fermenting process in mead making, Qureshi and Tamhane (1985) immobilized yeast cells in calcium alginate cells. Improvements in taste are said to be obtained by flash heating the must, before adding the yeast, or 30 seconds to 102^{0}C and instant cooling to 7^{0}C (Kime et al., 1991).

Fermentation has to take place in the absence of air (oxygen) in appropriate containers, preferably made from ceramics, stainless steel or glass or in wooden barrels. To exclude outside air a special fermentation lock is placed in the opening of the container, so that gas from the fermentation can exit, but outside air cannot enter. This is important, particularly towards the end of fermentation when less gas is produced inside. If too much oxygen enters, the mead will turn into vinegar. The simplest method, but not a completely safe one, is to place a cotton ball in the opening of the container or in a perforation of the stopper. Another improvisation is a plastic hose leading from the same perforated stopper into a glass of water, with the end of the hose always submerged in water. The glass always has to be kept at a lower level than the end of the tube in the stopper as a precaution against sucking the seal water back into the fermentation vessel.

a)

b)

Figure 2.16: a) Section comb honey, stored by bees

directly in special round or square clear plastic sections. b) Decorative wooden sections are prepared with a thin foundation sheet and placed in supers in lieu of frames and in the same manner as plastic sections.

During fermentation the must should be maintained at a constant temperature of 20� to 25 ^{0}C (18 ^{0}C according to Morse and Steinkraus, 1975) but not exceeding 28 ^{0}C. The exact temperature is not absolutely critical since fermentation will also take place at other temperatures but at different speeds. The longer the fermentation, the greater the risk of contamination by other bacteria or yeasts will become. At higher temperatures fermentation will be faster, but will produce less alcohol. At lower temperatures fermentation will become progressively slower and eventually stops.

After 2 to 3 days of fermentation, an oxygenation of the mead by decanting it into another container may be beneficial but not necessarily so. Once fermentation has slowed down however, decanting is beneficial to prevent the mead from becoming bitter from the dead yeast accumulated at the bottom of the container. Otherwise, the must is left undisturbed for approximately one month or until no more gas exits from the fermentation lock. The liquid is then carefully poured or syphoned off with a hose, without disturbing the sediment. This decanting is not enough to clarify a mead made from only honey. For complete clarification, extremely fine filtration or the addition of precipitating agents such as tannins (2.5 g dissolved in alcohol, per 100 litres), bentonite (100 g/l00 1) colloidal protein solutions or egg white beaten very well (the whites from 2 eggs for 100 1) is necessary. After a few days the liquid is syphoned off again or filtered. Alternatively, boiling the must prior to fermentation will precipitate most of the proteins responsible for clouding mead (Berthold, 1988a) but will also eliminate most of the honey aroma.

Finally, the mead has to be aged to develop its flavour. The use of oak barrels is best, but aging in bottles is possible. Different preparations reach maturity at different ages (6 months to 3 years) but at least 18 months

should be considered. For commercial operations the addition of a preservative like potassium sorbate (15 - 20 gibO 1) may be used or the mead may be pasteurized immediately prior to bottling.

For the production of <u>vinegar</u> it would be advantageous to start the mead with a must of half the concentration of honey, but the same amount of nutrients. After one month of alcoholic fermentation (in the absence of air) a culture of vinegar bacteria (<u>Acetobacter aceti</u>) are added. Alternatively, a little of ready-made vinegar may be added, but not commercial, pasteurized vinegar. The containers are then left open to the air, but should be covered to prevent dust and other debris from entering. At 20� to 25�C and with sufficient bacteria, the process can be completed in just a few days, but would more likely take 1 to 9 months. After occasional tasting or acid testing to determine the point of maturity, the vinegar can be bottled for sale or personal consumption. A level of *5* % acid (by volume) is considered mature.

The following is a step by step description of the basic mead making process as adapted from Steinkraus and Morse (1966) for a dry (non-sweet) mead from white clover honey with a final alcohol content of about 12% by volume. This approach is rather "high-tech" and nutrients may be hard to get, but it demonstrates the necessary points of production control. For most productions, the nutrients can be simplified (see following recipes).

1. ***Nutrients for one litre of must:***

5.000 g	*Citric acid (or 2.528 g citric acid and 2.468 g of sodium citrate, which require less pH adjustment)*
1.229 g	*Ammonium sulphate*
0.502 g	*Potassium phosphate (K2PO4)*
0.185 g	*Magnesium chloride*
26.42 mg	*Peptone*
52.80 mg	*Sodium hydrogen sulphate*

5.28 mg	*Thiamine (vitamin B_1)*
2.64 mg	*Calcium pantothenate*
1.98 mg	*Meso-inositol*
0.26 mg	*Pyridoxine (vitamin B_6)*
0.013 mg	*Biotin (vitamin H)*

- Honey is diluted to 21 % solids with water. If crystallized, the honey is heated to 60-65 ^{0}C to facilitate dissolution;

- all of the above nutrients are added to the diluted honey;

- the pH is adjusted to 3.7-4.0 with sodium hydroxide or hydrochloric acid;

- when cooled to about 27^{0}C, the 150 litre batch is placed in a 200 litre oak barrel;

- the batch is inoculated with 0.5% by volume of active yeast culture and sealed with a fermentation lock (}or preparation of such a growing yeast culture see the second recipe);

the mead is maintained at 18 ^{0}C during fermentation;

- after 6 months of aging it is decanted and filtered through Celite 503 or similar filter-aid, to remove yeasts;

- total acidity is adjusted to 0.6% with citric or tartaric acid;

- the mead is pasteurized at 63 ^{0}C for 5 minutes and bottled while hot.

Other possible modifications such as decantation, pasteurization, disinfection, nutrient alternatives, filtration, clarification, fermentation temperatures and aging have already been discussed.

2) Gonnet et al., (1988) recommended the preparation of a starter culture of yeast particularly for larger batches. The following proportions are for such a starter batch. The final must therefore consists of: 1) a sugar and water mix, at a ratio according to previously mentioned criteria; 2) nutrients added in the same quantities per litre as given for the starter batch below and 3) the yeast starter batch at 2% by volume of the total must.

Ingredients for the starter batch:

10 l	*Water*
1.5 kg	*Honey*
1.1 kg	*Selected yeasts*
29.5	*Nutrient salt mix*

The honey is dissolved in the water and at 25 ^{0}C the nutrient salts and yeast are added. Mix well and leave for three days at 25 ^{0}C in a container sealed with a fermentation lock. After that, once stirred well, it can be added to the final must at 2% by volume.

Nuteients per litre of must or starter batch:

0.250 g	*Diammonium phosphate*
0.250 g	*Potassium bitartaric (cream of tartar)*
1.875 g	*Trataric acid (or 1.750 g of*

	citric acid)
0.050 g	*Potassium metaisulphite*
0.250 g	*Yeast extract*

3) Soldati and Piazza (1985, unpublished communication) following nutrients per litre of must (and many other ingredients with no apparent difference due to use of lower describe the use of the variations of these basic or higher concentrations):

2.00 mg	*Ammonium sulphate*	*or*	*750 mg*	*Ammoinum carbonate*
0.75 mg	*Potassium metabisulphite*		*1000 mg*	*Ammonium phosphate*
1.00 mg	*Citric acid*		*500 mg*	*Citric acid*
0.25 mg	*Vitamin complex (unspecidfied)*			

They start with a 1.3 mixture of honey and water and a Baume' (a unit to measure sugar content) reading of 13.5�* **to 14.5�**. After the initial pasteurization and addition of the nutrients, 10% of the must is used for a starter batch to which the selected yeasts are added. One to two days later when the yeasts are fully active, the starter batch is added to the rest of the must. when the must has reached a Baume' of*** **0.1�*****, for a dry mead (or earlier if so desired), fermentation is interrupted by transferring the liquid (without sediment) into another container in which the (second) fermentation continues for another 15 to 30 days. At this point the mead is clearer and can be filtered and bottled. For storage reasons, the mead should have at least 10% alcohol and not less than 3.5 g/l acidity, measured as tartaric acid.***

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2.12.5 Honey beer

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Honey beer is easier and faster to make than mead. It cannot be stored for more than a few hours but once it has become flat, it may be revitalized by addition of more honey. Across the African continent, there are many ways of preparing this popular beverage. Without knowledge of microbiology some ingenious ways have been designed to maintain yeast cultures and inoculate subsequent batches with the desired kind of yeast. Uncontrolled as the process might appear to the uninitiated, there are brewers who have excellent control without knowing the biological background of the brewing process. The following are a few recipes from East Africa.

1) A typical commercial honey beer in Kenya is described by Paterson in Crane (1975) as containing a considerable amount of refined cane sugar, jaggery or freshly squeezed cane juice. The higher the honey content though, the better the beer is considered. Paterson mentions a recipe of 27 kg of honey with 108 kg of sugar in

250 litres of water. To a large 200 litre drum or barrel 20 to 30 slices of the muratina or sausage tree, Kigelia aethiopica (Bigniniaceae) are added. Besides supposedly giving strength (higher alcohol content?) and flavour to the beer, the slices probably also serve to inoculate the beer with the right kind of yeast. After fermentation, the beer is crudely filtered and the muratina slices are removed and dried for use in the next batch. Production takes several days to complete.

2) Kihwele ~ersonal communication) from Dar-es-Salaam, Tanzania, uses 5 litres of honey in 18 1 of water to which he adds 6 teaspoons of dry yeast. The fermentation, taking place in a dark, warm place will allow consumption after 5 to 7 days. In a similar recipe, one of the authors (Krell) not wanting to go through the lengthy process of the third recipe, made batches of honey beer with honey to water ratios of approximately 1

.~4 using dry baking yeast and no additional yeast nutrients. The higher the initial amount of yeast, the sooner the fermented product is drinkable (1 to 2 days). Larger amounts of yeast, such as 10 teaspoons of dry yeast per litre, left a strong yeasty flavour in the beer. Even starting smaller amounts of yeast a day ahead and adding them to the final batch never provided a beer that was drinkable in less than 24 hours. However, the same author has seen brewers in Zambia prepare a batch within 6 hours from a yeast starter batch.

Figure 2.17: Honey beer fermentation can be so rapid that the broth appears to be boiling.

3) None of the traditional beer brewers use cultured yeasts, but many know how to prepare special nutrient "cakes", possibly containing some of the right yeasts, or they know how to reinoculate (as described in the first recipe). The following recipe is a traditional method from Zambia and has been documented by Clauss (personal communication). The starter is also used for making maize (corn) beer and is the same one seen by one of the authors in the almost "instant" beer production mentioned under 2). The first and/or second batch are a little slower, since the yeast population still has to build up. Reusing the dried cake, however, or even a left over *portion of the beer with a new cake will allow much faster fermentation.*

- *Soak some maize until it germinates, then dry it (toast it in a hot pan if desired) and pound it into a relatively fine powder,*
- *Repeat the same process with finger millet (Some brewers do not roast but only sun-dry the germinated seeds, since the toasting may add flavour);*
- *Mix the maize and millet flour and boil slowly in a good quantity of water for a long time until the volume is reduced to a quarter, i.e. from 20 litres to 5 litre, or until a pasty consistency is reached;*
- *Leave it to cool and wait one week,*
- *Add some raw germinated millet flour and lukewarm water and stir everything into a thick paste.*

The paste is now ready to be added to a 1:4 mixture of honey and water. Amounts and ratios vary considerably and depend on each brewer's experience. By using this starter, a batch of beer can be produced in half to one day. Modifications apparently allow some brewers to produce the beer even faster (see Figures 2.17 and 2.18).

Addition of pollen and brood is accidental. While pollen may add nutrients for the yeast, the brood mostly causes acidity and off-flavours in the beer. It should therefore be avoided as much as possible.

2.12.6 Honey liqueurs

The following 4 recipes are taken from a promotional leaflet for various liqueurs which was printed in 1903. The alcoholic portion of the liqueur is not derived from honey fermentation, but through the addition of alcohol in its pure form or as a distilled beverage such as aquavit, schnaps, gin, vodka, cachassa, rum or arrack.

1) Macerate 2 kg of aromatic, juicy, finely chopped fruits in 2 litres of alcohol (70 to 96%). Keep in a well covered container or sealed bottle. After one month filter and press out the fruit through a very fine cloth. To this liquid add 2.25 kg of honey dissolved in 2 litres of boiled water.

2) In another method, practically the same as above, the alcohol is substituted by aquavit (a distilled grain

alcohol of 40 to 60% alcohol by volume). After maceration and filtration, 375 g of honey are added directly for every litre of alcohol/juice.

3) Similarly, one might use aromatic herbs, flowers or spices instead of, or in addition to the fruits For example, 50 g of dry orange peel are macerated in one litre of alcohol (70%). After 15 days the mix is filtered and 600 g of honey, dissolved in 600 ml of water, is added.

Figure 2.18: Beer brewer selling her product from traditional gourds.

4) The honey itseij may be the only aromatic substance added to the alcoholic beverage like honey aquavit or honey whisAy. It is added to the distilled beverage either directly or with a little water. The quantities vary with the desired results, but the choice of honey is extremely important to harmonize flavours.

2.12.7 Honey spreads

To avoid separation of honey and pureed fruits or nuts only crystallized honeys should be used. There are basically two techniques. The ingredients are mixed with the liquid honey at the same time as the seed crystals or they are mixed after the crystallization has been completed, to obtain either a hard or soft product, respectively. To mix dried fruits with crystallized and softened honey in small batches, a clean meat grinder may be used.

In the following recipe apricots have been used but other fruits can be selected and fruit proportions be increased until those of fruit spreads and marmalades are reached. When changing the type of honey and fruits, care should be taken that their flavours are compatible.

Ingredients (in parts by weight) after Berthold (1988b)

8.5	*Light coloured honey (liquid or liquified)*
1	*Seed honey (finely crystallized)*
0.5	*Dried apricots (very dry, high quality)*

If the moisture content of the honey is high and fermentation is possible, pasteurize the honey after mixing with the pureed or ground fruit at 65 ^{0}C for 10 minutes. Add the seed honey to a small quantity of liquid honey. when evenly mixed, add to the rest of the liquid honey fruit mix. If a meat grinder is available and fermentation risk is low, the dry fruit and the seed honey plus a small quantity of liquid honey may be passed through it twice. Mix thoroughly with the liquid honey and fill into clean, wide-mouthed jars. Seal and leave to stand at 14 ^{0}C for at least 5 days or until crystallized. Finally, clean the outside of the jars and apply an attractive label.

Honey tahena paste

Ingredients (in parts by weight) modified after El-Shahaly et al., (1978):

63	*Honey (creamed)*
37	*Tahena (sesame seed butter)*

Prepare the sesame seed butter (chop sesame seeds in a blender or grind until fine), emulsijy to prevent oil separation and add the honey. Optional additions are 0.1 part artificial honey flavour, 3 parts sorbitol (to decrease desiccation of the paste) or 2 parts lecithin (to improve texture and spreadability). Creamed honey should be used. Packed in either wide-mouth jars or aluminum tubes, the paste should be refrigerated at 6^{0}C to prevent changes in appearance (oil separation) and organoleptic characteristics which may occur in even relatively short periods of time.

Dulce de Leche

For this very popular Argentinean spread which is normally made with refined sugar, honey is dissolved in a small amount of water. Milk is added, mixed well and boiled careflilly while stirring until the mixture has a creamy, paste-like consistency. Proportions may vary from 1:8 to 1.1 for the honey and milk depending on the desired flavour and consistency. Preparation from dried milk dissolved in very little water is possible and faster, but less heating will result in other flavours.

2.12.8 Honey with fruits and nuts

Fruits in honey

Sun-dried fruits with as low a moisture content as possible should be used, but they should still be soft. They can

be placed directly into the honey, either whole, chopped or pureed. Partially dried fruits or those with a high moisture content even when dried should be covered with honey for a few days in a sealed container. After the honey is poured off the process can be repeated two or three times until the honey is no longer diluted with water quice) from the fruits. Then the fruits can be mixed with the final batch of honey and bottled. This process is necessary since the juice in the fruit will add too much water to the honey. Pasteurization of both fruits and honey will improve hygiene and storability and will reduce the risk of fermentation, but may affect the flavour. The diluted honey which is removed during the process can be used as fruit syrup preferably after being pasteurized.

Nuts in honey

The previous process can be repeated with nuts, but as commercially available nuts are already fairly dry, they do not usually need to be dried any further. Care should be taken that the honey flavours mix well with the chosen nuts. Since a nut and honey mix can also have a considerable aesthetic appeal, light coloured, liquid, slow crystallizing honey should be used. Distinctive glass jars can add flirther consumer appeal (see Figure 2.5).

If bottled by hand, or if the bottling machine allows, honey and nuts can be mixed before bottling. Otherwise the correct amount of honey should be placed into the jar and the nuts added later. The correct ratios need to be adjusted for each nut type. Nuts should be tightly packed so that they cannot float to the top and leave a pure honey stratum at the bottom. Some packers use a special clear plastic insert to keep the nuts from floating to the top.

2.12.9 Honey with pollen and propolis

Ingredients (in parts by weight):

1000	*Honey*
100	*Propolis*

125 Pollen

1-3 Royal jelly (optional)

Finely grind the dry pollen pellets and the hardened frozen) propolis. Warm 200 parts of honey in a water bath and mix in the pollen and propolis powder. After a few minutes of cooling stir the mixture into the rest of the honey. If refrigerated, the honey will stiffen and have less of a tendency to separate. Royal jelly might be added as well or propolis extract (paste) may be used instead of raw propolis. Propolis and pollen can also be mixed in equal volumes. It would of course be best to include all these ingredients in crystallized (creamed) honey before or after crystallization.

2.12.10 Honey paste for dressing wounds

Pure liquid honey or honey mixed with other beneficial creams or ointments may be used to dress wounds. The following is a very versatile paste useful as a home remedy for many ailments.

Ingredients (in parts by weight) after Uccusic (1982):

10 Wax

3 Propolis extract (10% ethanol extract)

2 Honey

Melt the wax and during cooling mix in the propolis extract and finally the honey. Store in a tight jar in a cool and dark place. This paste can be applied on all kinds of sores and open wounds, can be cliewed for mouth infections like paradontosis or used for skin damaged due to radiation, poisoning or acid burns. For serious infections or wounds, however, a doctor should be consulted.

2.12.11 Sugar substitution

Honey can replace cane sugar in almost any recipe. Since honeys are of different flavours and compositions, however, such replacements may result in changes of flavour, consistency, cooking times and the quantities of other ingredients required. In industrial baked products honey is therefore only used to replace small quantities of sugar. In addition, strong flavoured or dark, cheap honeys are preferred since less honey is required to obtain some honey flavour and consequently, less of the cheaper sugar has to be replaced. When substituting most or all of the sugar with honey, mild-flavoured honeys may be more desirable as they will not overpower other flavours of the product.

Since honey is denser than crystallized, packed sugar and therefore has greater sweetening power per volume than sugar, most cookery books recommend the use of 1 cup of honey for 1 � cups of sugar or that 1 cup of sugar can be replaced by 4/5 of a cup of honey. Recommendations are not uniform, and others recommend replacing 1 cup of sugar with only � to *³A* of a cup of honey. When recipes are given in weight, honey can be substituted approximately 1:1 or, considering the moisture content, add up to 20% more honey in weight than sugar. The extra water added in the form of honey needs to be accounted for as well. Thus for every cup of honey added, approximately 1/5 to � of a cup less liquid should be used in the recipe. By weight: for every 1 kg of sugar substituted by 1000-1200 g of honey, 180-200 g (180-200 ml) less water should be used. For most corn syrups, honey can be substituted 1:1 by weight as well as by volume, even though corn syrup often contains more water than honey. For industrial quantities more specific calculations based also on the sugar composition of the specific honey, are necessary.

Too much honey in a recipe may cause too much browning in a baked product. To neutralize the acidity of honey (unless sour cream or sour milk is called for in the recipe) add a pinch of baking soda. If honey is substituted in jams, jellies or candies, slightly higher temperatures must be used in cooking, but conversely, when baking bread, lower temperatures are required. In candies, more persistent beating (mixing) and slightly higher caramelization temperatures are needed. Also careful packaging and storage of the final product may be required to prevent absorption of atmospheric moisture.

When using honey for a recipe that also involves use of oil or fat, measure the oil or fat first in the measuring container. Removal of honey from the same container will then be easier and more complete.

2.12.12 Fruit marmalade

This marmalade is special in that it uses pre-dried fi~uit pulp, which reduces cooking time and thereby also preserves a much better flavour and uses less energy (fuel wood). It also uses less sugar than other traditional recipes, yet preserves well. Though originally formulated for sugar, a portion of the sugar can be replaced. By replacing only 5 to 10% of the sugar with a mild honey, the flavour can be slightly improved. Using more honey will produce a stronger honey flavour and increases the cost. The original recipe had been formulated by G. Amoriggi (personal communication) for small to medium scale processing using sun-dried pulp. Many more food canning and preservation recipes can be found in Geiskopf (1984).

Ingeredients

10 kg	*Fruit pulp (fresh)*
6 kg	*Sugar (or 5.4 kg sugar and 0.6 kg honey)*
40 tblsp.	*Lemon o lime juice, i.e. 4 tblsp./kg pulp (or 10 teasp. Of citric acid, i.e. 1 teasp./kg pulp)*

The recipe is best with pure mango or a papaya and banana pulp mixed at a ratio of 7.~3. Extract the pulp and mix with haij of the sugar and haij of the lemon juice (no honey yet). Spread in layers of 1 - 1.5 cm on trays of stainless steel, aluminum or aluminum foil, cover the pulp to protect it from insects, mice etc., and place it in a solar drier.

If a refractometer is available, the pulp is left in the drier until it has a <u>minimum</u> sugar content of 43 - 45% total solids. ft is then transferred into a pot where the other haij of the sugar and lemon juice and all the honey are

added. The paste is simmered over medium heat until it reaches a sugar concentration 67%. Continuous stirring is necessaiy.

If a refractometer is not available, leave the pulp in the solar drier for approximately 7 hours of continuous sun (e.g. from 9 am to 4 pm) and leave on the stove until it "looks" like marmalade (or until it reaches approximately 105 ^{0}C).

If part of the sugar is replaced by the honey, the honey should not be added to the pulp batch before solar drying, since it will make drying more difficult and prolon ged. Honey may also be added when reducing and heating of the pulp is almost complete. Instead, the honey should be added as late as possible during the finale slow boiling of the paste so as to preserve as much of the beneficial characteristics and flavour of the honey as possible. The moisture content of the honey is not important and the ratios of sugar to honey can be changed as well, but the product will have to be heated slightly longer to reach the same sugar solids percentage.

2.12.13 Honey jelly

This jelly recipe follows the instructions of a pectin manufacturer, Unipectina Spa in Bergamo, Italy.

Ingredients for 1 kg of honey jelly:

220 g	*Water*
3-4 g	*Pectin*
800 g	*Honey*
1.5-2 ml	*Tartaric acid (at a concentration of 50% weight/volume in water)*

The pectin is soaked in the cold water, dispersed by stirring and brought to a boil which is continued until the weight has been reduced to 200 g. Then the honey is added and heated to 60^{0}C. The heating is stopped, the acid added and the mix poured into moulds or other containers.

If no mechanical mixer is available, the pectin can also be dispersed in a small quantity of honey and the water be added to this paste. To avoid fermentation, the mix may be heated to 77^{0}C and bottled without any other sterilization or it may be heated to 60-65 ^{0}C and bottled in sterilized jars. The final solids content should be 65-68% at a pH of 3.1-3.3. The honey acts here as a sweetening as well as a flavouring agent. Parts of it can be replaced with fruit juices or purees to provide other flavours.

2.12.14 Syrups

Honey fruit syrup - from a promotional pamphlet of 1910

Obtain or press a good quality, clean and fresh fruit juice. Filter it and add honey at a ratio of 5:3 (honey to juice) by weight Boil to sterilize and bottle. To prepare a drink, it is diluted with water. The fruit juice and honey mix from section 2.12.8. can be heated for pasteurization and bottled hot after any necessary correction of concentration.

Honey-fruit-vinegar syrup - from a promotional pamphlet of 1903

Ingredients (in parts by weight):

1	*Fruits (juicy and cromatic)*
1	*Vinegar*
2	*Honey*

Place fruit (whole or cut, according to type) in the vinegar. Let it soak for 5 days, occasionally stirring and squeezing more juice out of the fruits. Press the liquid through a fine cloth and add the honey. Boil for 5 minutes only and bottle. This syrup is diluted with water (3 tblsp. of syrup per glass) for a refreshing drink.

Syrup base for herbal preparations

Dissolve 2 to 3 parts of honey in 1 part of water and heat to 65 ^{0}C for a few minutes. To this syrup various plant extracts with therapeutic or aromatic effect can be added.

If the plant extracts were made with alcohol the storage life of the syrup is increased. Otherwise some alcohol may be added as a preservative.

2.12.15 Rose honey

1. *Ingredients (in parts by weight) after the Italian Pharmacopoeia from Negri (1979):*

20	Honey
4	Red rose petals (aromatic variety)
5-7	Boiling water

Prepare an inflision (tea) of the mashed rose petals in the boiling water and leave for 24 hours. Filter through a very fine cloth and press out. Mix the rose water with the liquid honey and leave in the cold until it reaches a density of 1.32. This mixture has a limited storage life. As an alternative to the last stage, boil the mix briefly and bottle while hot.

1. Ingredients (in parts by weight) after the German Pharmacopoeia from Negri (1979):

1	*Rose petals*
5	*Ethanol (ehtyl alcohol, 65%)*
1	*Glycerol*
9	*honey*

Mash and soak the rose petals in the alcohol for 24 hours. Filter and press the obtained liquid and mix with the other ingredients. Reduce to a final volume of 10 parts by heating in a water bath. As an alternative to the last stage, the mixture can be boiled briefly and bottled hot.

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2.12.16 Caramels

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General considerations

Caramels and candies offer a large variety of products in terms of flavour, colour, consistency and shape (see Figure 2.19). Candy making is an art of its own. The consistency of the candies depends very much on the temperature reached during heating and a candy thermometer would therefore be very useful. Other tests can be used to estimate the right temperature which is particularly important since adding honey to a recipe requires a higher temperature for caramelization which cannot always be calculated in advance.

With sufficient experience, the colour, boiling behaviour and threading of candy can be used to recognise the critical temperatures. For testing, fresh and cool (preferably chilled) water should be used each time and the pan should be removed from the heat in order to avoid overheating during the test. The following description of the signs for different stages of caramelization and candy processing is adapted from Rombauer and Rombauer Becker (1975).

Figure 2.19: Various caramels, jellies and gums made with honey. One type, on the right, is also flavoured with propolis.

-A thread stage is reached when the candy forms a 5 cm coarse thread when dropped from a spoon. Begins at 110^{0}C.

-The soft ball stage is reached when a small quantity of syrup, dropped into chilled water, forms a ball which does not disintegrate, but flattens out of its own accord or when gently picked up with the fingers. Begins at 1 12^{0}C.

-The firm ball will hold its shape and will not flatten unless pressed with the fingers. Begins at 117^{0}C.

-The hard ball is more rigid, but still pliable. Begins at 121^{0}C.

-The soft crack stage is reached when a small quantity of the hot syrup, dropped into chilled water, will separate into hard threads which, when removed from the water, will bend. Begins at 132^{0}C.

-The hard crack stage is reached when the same threads are hard and brittle. Begins at 149^{0}C.

-Caramelized sugar is obtained at 154� to 170^{0}C when a pure sugar syrup turns golden brown. It will turn black and lose its sweetness at about 177^{0}C.

During heating the temperature rises slowly up to 105 ^{0}C, but will increase much more rapidly thereafter. It should be carefully watched and controlled. Preheat the thermometer in hot water before inserting it into the candy and make sure that it does not touch the bottom of the pan. After the ingredients have been well mixed and the temperature reached 100 ^{0}C, stirring should stop. Do not scrape the edges of the pan once the boiling stage has been reached as the sugar crystals on the edge will cause the candy to granulate rather than stay smooth. When the boiling point has been reached, just cover with a lid and in 2 to 3 minutes the steam will have washed off the sides. Uncover and continue without stirring. If granulation occurs anyway, add a little water and start again.

The pan should not be disturbed during cooling or when removing it from the heat for testing without a thermometer. Use only a very clean spoon for testing. The cooling candy should never be beaten, kneaded or mixed before it has cooled to 45 ^{0}C.

There are two ways of cooling. The pot can be placed immediately into cold water until the pot bottom can be touched without discomfort. The other way, as described in these recipes, is to pour the hot candy onto a cold and buttered marble slab, a heavy buttered platter or a cooled tray. Pour the candy carefully as it may splash and burn somebody. Also, let the candy run from the pan and do not scrape out the stiffer material at the bottom which may have reached a different stage of crystallization and may behave differently if mixed with the rest of the batch. If adapting sugar-only recipes for use with honey, remember also that honey needs higher temperatures to reach the appropriate stage of caramelization and may require more beating (kneading) if the recipe requires it.

Should the candy have cooled too much for further processing, the mass can be carefully tesoftened in a water bath. If the syrup was cooked at too high a temperature and crystallized too hard, the candy can be reheated in a water bath with about 18 to 20% of water added and stirred constantly until it is completely liquefied. It can then be returned to the pan and heated to boiling point, covered to remove crystals from the sides of the pan, uncovered and reheated to the appropriate caramelization point.

Colouring and flavouring should proceed once the candy mass has cooled to a temperature manageable for kneading or stirring (less than 45 ^{0}C). Food aromas can be incorporated at the same time. While still pliable, other ingredients such as candied fruits, nuts, ginger, coconut or jam can be added. These are more likely to be added to candy heated only to the soft ball stage. Once kneaded or mixed in, the candy can be cut into the desired shapes and coated with confectioners sugar or chocolate.

Coating with chocolate is rather tricky and requires correct environmental conditions as well as special packaging and is not possible without refrigeration in hot climates. The weather during dipping should be cool and dry, or the room should be cooler than 21 ^{0}C with a relative humidity of less than 55% and should be free of draughts. Any type of bar chocolate is very slowly melted in a water bath. The chocolate is stirred until it reaches 54 ^{0}C. If it is not stirred constantly at temperatures above 38 ^{0}C, the cocoa butter will separate out. Remove from the heat but maintain the temperature at about 31 ^{0}C. The candy needs to be maintained at about 21 ^{0}C. Dip candies one at a time and let them drain on a wire rack or screen. If large quantities are prepared, the dipping should be done

in a smaller, separate container. The drippings can be remelted again. The extra chocolate on the dipping fork can be used to make small designs on the candy to distinguish different fillings. Refrigerate the product for a few hours before packing.

Honey caramels

Ingredients (in parts by weight) after Paillon (1960):

0.75	*Honey*
6	*Sugar*
0.75	*Glucose*
2	*Warm water*
q.s.	*Vanilla powder, alcohol extract etc.*

Heat the water in a large skillet (frying pan). Ensure that no odd flavours from the skillet can affect the product. Reduce the heat and dissolve the sugar in the hot water, stirring it to avoid caramelization on the bottom. Add the glucose, which is placed to dissolve in the middle of the syrup. The glucose may be replaced by honey and added at a later stage. Let it simmer for a while. Skim off the foam and clean crystals from the edges of the pot by covering it for three minutes. Uncover, stir and heat until the hard ball stage is reached, between 1250 and 128 ^{0}C. Use a thermometer or drop test for control. Add the honey and aromas and continue heating until the soft crack stage is reached at 145 ^{0}C. Pour the hot liquid onto a cold and greased su~ace or tray. Allow to cool sufficiently until a good malleability ~liabihty) is reached, spread it evenly and stamp or press out the desired shapes or forms. Let it cool for a few moments and cover with sugar crystals or powdered sugar prior to packing. These caramels can be flavoured with honey only or with other essences and herbal extracts such as vanilla, eucalyptus, liquorice or mint. The cutting has to be done relatively quickly before the caramel becomes too hard.

Butter honey caramels

Ingredients (in parts by weight) after Paillon (1960):

2.5	*Sugar*
0.8	*Warm water*
4	*Glucose*
1.5	*Honey*
0.625	*Butter*
q.s.	*Salt*

Wet the sugar with the warm water, heat slowly and melt. Continue stirring and add the glucose, melt and heat slowly to 118^{0}C. Add the butter and honey, bring slowly back to 11 7^{0}C or possibly 118^{0}C. Spread quickly on a cold, buttered marble suiface between two metal or wooden bars and cut rapidly with a circular knife (a round, rotating blade). Pack while still warm.

Coconut fudge

Ingredients (in parts by volume) modified after Rombauer and Rombauer Becker (1975):

24	*Sugar*
12	*Honey*
8	*Milk*
1	*Vinegar*

q.s.	*Salt*
20	*Moist, shredded coconut*
3	*Butter*

Stir the first S ingredients together over medium heat until the sugar is dissolved. Stir until boiling then cover for about 3 minutes to remove crystals from the sides of the pan. Uncover, reduce heat and cook slowly to the soft ball stage (115 to 118^{0}C) without stirring. Remove from the heat and stir in the coconut and butter. Pour the hot candy onto a buttered platter or pan until it is cool enough to handle, then shape it into small balls or other preferred shapes. Place them on foil or wire racks to dry. Wrap the pieces individually for packaging. For small trial batches, 1 part could be equivalent to 1 tablespoon and 16 parts equal to 1 cup.

Honey roasted nut bars

The following recipe is very flexible since the proportions of sugar, honey and nuts can be varied in order to produce either a solid caramel bar with a few nuts, or nuts coated with caramelized sugar and honey (see Figure 2.19). Availability of moisture-proof packaging materials and economical (cost) considerations determine whether the honey proportion can be increased.

Ingredients (in parts by weight) modified after Paillon (1960):

		Possible range in %
10	*Sugar*	*10-80*
2.5	*Honey*	*0-75*
1.25	*Almonds or other*	

	nut, whole or broken	*0-80*
2.5	*Water*	*25-35 (on sugar)*
1.25	*White vinegar*	*0-50 (on water)*

Dissolve the sugar in the water and vinegar, place over medium heat and stir continuously. when boiling, add the honey, mix and reheat to a boil; cover for three minutes to remove crystals from the side of the pan, uncover and without stirring bring to a golden brown soft or hard crack stage according to preference. Add the nuts and cook for a few more minutes without raising the temperature. Then pour onto a cold, lightly oiled marble plate or buttered tray. Cut before the candy turns hard and wrap after cooling in moisture sealed packages or place in large glass jars for display. For candy coated nuts, with a higher proportion of nuts to sugar, the nuts should be stirred or shaken in a small amount of hot syrup. They may also be boiled briefly with the syrup. It may be found easier to immerse the nuts in a larger quantity of syrup and drain excess syrup while cooling on a wire rack. The drained candy can be reheated again after adding extra water (see general introduction to this section).

In Greece, the above recipe is popular in proportions of 1 part sugar, 5 parts honey and 5 parts roasted sesame seeds. Greek halvah (see below) is a spicier version and demonstrates another variant of this recipe.

Greek halvah

Ingredients (in parts by weight) after Crane (1975):

5	*Honey*
3	*Olive or sesame oil*
2	*Chopped or ground nuts (alos sesame seeds)*

10	*Sugar*
5	*Flour*
3	*Water*
q.s.	*Ground cloves and ground cinnamon*

Heat the oil until it is very hot. Then gradually pour in the flour, stirring slowly until the flour turns brown (30-45 minutes). Meanwhile make a syrup of the sugar, honey and water, boil it for approximately 30 minutes over low heat until a soft crack stage is reached. Add the spices and nuts and also mix in the browned flour. Stir constantly over low heat until the mass has thickened. Turn off the heat and cover the pan for 5 minutes, then pour onto an oiled baking sheet, marmor or pan. when cool, cut into squares or bars and sprinkle with icing sugar or cinnamon.

2.12.17 Nougat and Torrone

This preparation is very similar to ordinary candy preparations and general processing procedures described in the previous section.

Ingredients (in parts by weight) after Paillon (1960):

10	*Honey*
14	*Sugar*
3	*Water*
10	*Whole pealed almonds, blanched or toasted*
0.6	*Unsalted, dried or blanched pistachio nuts*

2	*Confectioners sugar (powdered or icing sugar) eggs (whites only, from 4 eggs per kg of honey)*
q.s.	*Vanilla extract*
q.s.	*Wafers*

Figure 2.20: Torrone and various nut, sesame seed and granola bars made with honey.

Mix the sugar, honey and water at room temperature in a large and deep fireproof pan. Leave for about two hours, stirring occasionally until a syrup is formed. Then place on medium heat and bring to a boil while stirring, being careftil to avoid any caramelization at the bottom of the pan. when boiling, cover for 3 minutes until crystals on the sides of the pot have been removed by the steam. Uncover, reduce heat and slowly increase temperature

to 120-125 ^{0}C, according to the hardness desired in the final product. Remove from the heat and fold the previously mounted (beaten) egg whites into the hot syrup with either a wooden spatula or a mechanical mixer. Mix for a few minutes and when homogeneous, return the pot to low heat. Reheat to 120 ^{0}C while stirring. Once this candy has almost reached the hard crack stage, remove from the heat and add the warm, toasted almonds followed by the pistachio nuts and vanilla extract. Pour onto cold marble between two buttered bars of the desired height or into buttered trays dusted with confectioners (4)owdered) sugar. The trays or the marble slab may also be lined with baker's wafer paper, ostia or very thin wafers (all must be edible). Once levelled at the desired thickness (0.5 to 1 cm) the nougat should also be covered by the same wafers. Weigh down the wafers and allow to set in a cool, dry place for 12 hours, then cut or saw into desired shapes and pack.

Recipes for the Italian torrone and Spanish tor6n are very similar. The torrone is characterised by the addition of hazel nuts equivalent to half the quantity of almonds and omitting pistachios. (The overall almond and nut content is increased to 60% of total weight.) Also added are finely grated lemon peel and as an option orange peel (a tblsp. each per kg of torrone) or a tblsp. of citronel (candied citron-rind) instead of the orange peel. For small-scale home recipes caramelize the sugar directly in the pan and the honey in its own water bath. Fold the mounted egg white into the caramelized honey. Then, both hot portions are mixed and brought to the final temperature close to the hard crack stage. Other ingredients have to be mixed in very quickly, if they are not preheated. Cacao paste can be added as well to change colour and flavour, replacing up to 25 or 30% of the nuts. To complement the cacao flavour, the almonds should be replaced with hazelnuts and any citrus or citronel flavours can be omitted.

2.12.18 Honey gums

Ingredients (in parts by weight) after Paillon (1960):

3	*Gum of Senegal, of gum arabica*

2.3	*Water*
2.5	*Sugar*
1	*Honey*
0.6	*Glucose*
q.s.	*Aroma, flavouring essence or colouring*

Dissolve the gum in the water, warming it lightly while stirring with a spatula. Mix the sugar with the honey, add glucose and bring this paste to a boil in a water bath while stirring vigorously. Add the filtered gum solution to the melted sugars. Heat together and verif' the right stage of boiling by dropping a small quantity into some moulds. when the boiling is judged as having reached the right stage, all of the mass is poured at a temperature of 85 - 90^{0}C.

The moulds are prepared in wooden drawers or trays filled with a thick layer of starch. The desired form is created in the starch with stamps of the required shape. The liquid is carefully poured into these cavities with a fine-spouted container. Once cooled, the trays are turned onto a large mesh screen and the extra starch is collected below. The gums can be cleaned with a blow of air (do not blow on them by mouth). Once the excess starch is removed, the gums are humidified with a jet of steam, dusted with or rolled lightly in fine crystal or confectioner's sugar and dried for afew minutes in an oven before being packed.

Colours and aromas can be mixed with the water and added to the gum to create more variety. Flavours can also be mixed towards the end of the boiling phase.

2.12.19 Gingerbread

Under the name of gingerbread a number of different recipes in different countries are used. The typical recipes

from which it derived its name were those which included ginger and other spices that complement ginger, such as cinnamon and cloves. A recipe with wheat flour and one without wheat flour are given below. Measurements for small trial batches are given in brackets.

1) Ingredients (in parts by volume) modified after Rombauer and Rombauer Becker (1975):

5	*Butter*	*10*	*Honey*
5	*Sugar*	*10*	*Warm water*
	Eggs (1 per 5 cups, or per 0.5 kg of flour)	*0.3*	*Grated orange rind (optional)*
25	*All-purpose wheat flour*		
0.2	*Baking soda (2 teasp. Per 0.5 kg of flour)*		
0.1	*Baking powder*		
0.2	*Cinnamon and ginger, each*		
0.1	*Salt*		

Preheat oven to 175 ^{0}C. Melt the butter in a heavy pan and allow it to cool. Add the sugar and egg, then mix well. Sift together the dry ingredients: flour, baking soda, baking powder, spices and salt, and mix them well. In yet another pot dissolve the honey in the warm water and add the orange rind if desired. Alternately, add the dry and liquid ingredients to the sweetened butter, mixing well. Bake for one hour in greased trays. The dough should be 1.5-2 cm thick.

2) Ingredients (in parts by volume) for a wheatless gingerbread after Rombauer and Rombauer Becker (1975):

12.5	*Rye or rice flour (e.g. cups)*	*5*	*Butter*
12.5	*Cornstarch*	*10*	*Honey*
0.3	*Baking soda (3 teasp.)*	*5*	*Sugar*
0.2	*Baking powder*	*10*	*Warm water*
0.2	*Cinnamon*		*Well beaten eggs (4 per 0.5 kg of rye or rice flour)*
q.s.	*(or 0.05) ground cloves*		
q.s.	*(or 0.05) ground cloves*		

Preheat oven to 165 ^{0}C. Prepare and mix all ingredients as in the previous recipe. Combine both wet and dry ingredients, beat and knead until thoroughly mixed. Bake in a greased tray for 60 to 70 minutes or until the dough fails to stick to a thin wooden stick inserted in the mix.

3) The following recipe from Paillon (1960) may be modified by including eggs, changing flour types and replacing the ammonium bicarbonate with baking powder or with (1:1) tartaric acid and baking soda. The tartaric acid or baking powder should however not be added until the dough is ready to be baked. Ammonium bicarbonate, if it can be obtained, produces a longer lasting, crisper cookie. It needs to be pounded and dissolved in warm liquid prior to adding to the dough and evaporates relatively quickly if it is not stored in an airtight container. The very high content of raising agent (baking soda and ammonium bicarbonate) can be reduced with only minor changes in the consistency of the dough. A few nuts may be included as well as a good dose of ground cinnamon

and cloves. Conversely, the malt extract and glucose are not essential and may be omitted. Glucose can be replaced by honey or sugar. If brown colouring is necessary, caramelized sugar (heated until it is almost black in colour) can be used without greatly affecting the flavour.

Ingredients (in parts by weight):

4.5	*Wheat flour*	*0.5*	*Ground ginger*
0.5	*Rye flour*	*2.0*	*Cubed citron*
5.2	*Honey*	*0.12*	*Sodium bicarbonate*
0.05	*Malt extract*		*(baking soda)*
0.35	*Glucose*	*0.08*	*Ammonium bicarbonate (or baking powder)*

Careftilly bring the honey and glucose mix to a boil in a water bath and add the malt extract. Pour the hot liquid over the flour and spice mix. Knead the compact dough and include the rest of the ingredients except the ammonium bicarbonate. Retain at least two thirds of the ammonium bicarbonate or baking powder, and all of the tartaric acid, if used. Let the dough sit for one week in a wooden drawer in a cool place.

Preheat the oven to 160^{0}***C and continue preparations by kneading the dough until it turns white. Add approximately � litre of milk or water while kneading and add the rest of the ammonium bicarbonate, baking powder or tartaric acid. Spread the dough in a greased and floured baking tray and cut into rectangles of 7 cm by 3 or 4 cm. Paint with beaten egg and dissolved confectioners sugar (optional) then bake at 160 to*** 190^{0}***C, according to the thickness of the dough (testing as in the last recipe above). when the trays are removed from the oven, break the gingerbread into the precut portions.***

2.12.20 Marzipan

Ingredients (in parts by weight):

10	*Sweet almonds*
1	*Bitter almonds*
7	*Honey*
1.5	*Rose water*

Finely grind the peeled and blanched almonds. Add honey and rose water and then leave for a day. No baking is necessary. The rose water can be replaced with lemon or orange juice. The marzipan can be sold in all kinds of shapes and be covered with cocoa powder or dipped in chocolate. ft can also be coloured and used for decorations. The bitter almonds can be replaced by a few drops of bitter almond extract.

2.12.21 Honey in bakery products

Bread

For replacing sugar in any bread recipes see section 2.12.11. Only one simple bread recipe will be given here, as adapted from Crane (1980).

Ingredients (in parts by weight):

700	*Wheat flour (whole wheat flour can be used)*
450	*Milk*
7	*Honey*

20	*Fresh yeast (or 5 dried yeast)*
5	*Salt*

Mix the yeast and honey, add to the warm milk and leave for 10 minutes. Mix the shortening with the flour and the salt, then add the milk to form a smooth, elastic dough. Knead well and add water if necessary. Leave to rise for 2.5 hours (or until double in size) in a warm place (30^{0}C) and in a deep, greased, pre-warmed (30^{0}C) covered container. Then divide in two, knead lightly, leave to rest 10 minutes, form into loaves in baking tins, cover with a cloth (ensure that the cloth does not touch the dough) and allow it to rise in the same warm place again for an hour or until double in size. Then bake in a preheated oven at 220 ^{0}C for about 40 minutes or until golden brown. Recipes with baking soda instead of yeast are much easier and quicker, since no rising is required, which is a phase very sensitive to disturbances.

Coconut oat cookies

Ingredients (in parts by weight) adapted from Crane (1980):

25	*Margarine*	*20*	*Dried, shredded coconut*
4.5	*Honey*	*35*	*Brown sugar*
30	*Flour*	*0.4*	*Sodium bicarbonate (baking soda)*
25	*Rolled oats*	*3*	*Warm water*

Dissolve the baking soda in water. Thoroughly mix all dry ingredients. Melt the margarine and add the honey. Mix everything together in a bowl. Place small portions (tablespoon size) on a greased baking sheet, allowing space for spreading. Bake for 10-15 minutes at 180^{0}C, or until the desired crunchiness is obtained.

Honey biscuits

Ingredients (in parts by weight):

3.5	*Flour*		*Eggs (6 per kg flour)*
1.2	*Honey*	*0.1*	*Baking powder*
25	*Rolled oats*	*3*	*Warm water*

Warm the butter, mix it with the honey and slowly add the other ingredients. Cool the dough before rolling out small amounts on a floured suiface. Cut out shapes of biscuits and bake in a preheated oven for 15 minutes at 200 ^{0}C.

Honey peanut butter cookies

Ingredients (in parts by volume):

10	*Flour*	*4*	*Honey*
4	*Peanut (groundnut) butter*		*Eggs (8 per kg flour)*
1	*Margarine*	*0.1*	*Baking powder*
2	*Sugar*	*q.s.*	*Vanilla extract*

Prepare peanut butter in a blender or grind finely. Mix the first three ingredients then add the rest one after the other. when smooth, leave for a few hours or refrigerate. Place small amounts (tablespoon size) on a greased baking sheet, allowing sufficient space for spreading and bake in a preheated oven at 165 ^{0}C for 7-10 minutes, depending on the thickness of the cookies, or until they are golden brown.

[1] **This Chapter is a joint effort between Lucia Piana and Rainer Krell with the former having provided the bulk of the information (in Italian, translated in part by L. Persano Oddo).**

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CHAPTER 3
POLLEN

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3.1 Introduction

Innumerable stories and even more rumours exist about the mysterious powers of pollen and its nutritional value. Pollen is frequently called the "only perfectly complete food". High performance athletes are quoted as eating pollen, suggesting their performance is due to this "miracle food", just as the "busy bee" represents a role model for an active and productive member of society. Using suggestive names, labels and descriptions in marketing of various products containing pollen sometimes reach almost fraudulent dimensions, creating false hopes and expectations in people, often connected with high prices of the product. Such practices are untruthful, unethical and should be avoided.

It is however, often difficult for a lay person to verify the numerous claims, particularly those backed up with so-called reports from "doctors". Conversely, it does not always take a "scientific" study to prove that a food (or substance of herbal origin) has a medicinal or otherwise beneficial effect. Many times, modern science is not willing or able to prove beneficial effects according to its own rigid standards, methods and technologies. However, as a whole, caution should be exercised in accepting the many claims made to the credit of pollen and for that matter also for the other products incorporating products from the bee hive.

Pollen grains are small, male reproduction units (gametophytes) formed in the anthers of the higher flowering plants (see Figure 3.1). The pollen is transferred onto the stigma of a flower (a process called pollination) by either wind, water or various animals (mostly insects), among which bees (almost 30,000 different species) are the most important ones.

Each pollen grain carries a variety of nutrients and upon arrival at the stigma it divides into several cells and grows a tube through the often very long stigma of the flower. Growth continues to the embryo sac in the ovarium of the flower, inside which one egg cell will fuse with a sperm cell from the pollen and complete the fertilization. Depending on the requirements for this process and the mode of transport from one flower to the next, i.e. insects, water or wind, each species of plants has evolved a characteristic pollen type. Thus, the pollen grains from most species can be distinguished by their outer form and/or by their chemical composition or content of nutrients. The knowledge of this is used in the identification of paleontological discoveries (paleopalynology) and in the identification of geographic and botanical origin of honeys (melissopalynology).

To determine the value of pollen as a supplementary food or medicine, it is important to know that pollen from each species is different and no one pollen type can contain all the characteristics ascribed to "pollen" in general. Therefore, in this text, pollen will always refer to a mixture of pollen from different species, unless otherwise mentioned. A logical conclusion is that pollen from one country or ecologic habitat is always different from that of another. People who are allergic to pollen will have noticed this during their travels.

Figure 3.1 : Close up of a lily flower. The anthers (large yellow structures) release pollen in such abundance that it falls onto the petals. Note also the pollen grains adhering to the stigma surface. (Photo courtesy of F.Intoppa)

For those who see in nature something more than just the mechanical and chemical interactions of substances and organisms, it might be added that flowers form a very special part of plants. They carry special "energies" which are used in traditional alternative medicinal practices such as therapies with Bach flowers, aroma therapy or the use of numerous herbal teas. Such energies may well be carried by certain chemical substances other than water, but this is not necessarily the case, as for example, homeopathic preparations demonstrate.

Since pollen is a part of these flowers and in addition is or represents the male reproductive portion, it also has very special "energies" or values of its own. In a wider understanding in certain philosophical environments, special plant and pollen surface structures interact with cosmic energies and may acquire some of their characteristics by this means.

Apart from these less orthodox explanations, certain empirical results have in the past been described for the effects of pollen on humans and animals. These will be discussed under medicinal uses. As far as the miracle food aspect of pollen is concerned, the diversity of pollen must be emphasized again and the fact that some pollen types (i.e., pine and eucalyptus) are nutritionally insufficient even for the raising of honeybee larvae. In an excellent review, Schmidt and Buchmann (1992) compared the average protein, fat, mineral and vitamin content of pollen with other basic foods. Pollen was richer in most ingredients when compared on a weight or calorie content basis than such foods as beef, fried chicken, baked beans, whole wheat bread, apple, raw cabbage and tomatoes. While comparable in protein and mineral content with beef and beans, Pollen averages more than ten times the thiamin and riboflavin or several times the niacin content. Pollen is usually consumed in such small quantities that the daily requirements of vitamins, proteins and minerals cannot be taken up through the consumption of pollen alone. However, it can be a substantial source of essential nutrients where dietary uptake is chronically insufficient.

If the nutritional benefit of pollen in small dosages is accepted, as described in many non-scientific publications, it must be understood as a synergistic effect. That is, a wide variety of beneficial substances interact to improve absorbtion or use of the nutrients made available to the body from regular nutrition. Pollen nutrients may also balance some deficiencies from otherwise incomplete or unbalanced supplies, absorption or usage.

The pollen which is collected by beekeepers and used in various food or medicinal preparations is no longer exactly the same as the fine, powdery pollen from flowers. The hundreds or sometimes millions of pollen grains per flower are collected by the honeybees and packed into pollen pellets on their hind legs with the help of special combs and hairs (see Figure 3.2). During a pollen collecting trip, one honeybee can only carry two of these pollen pellets.

The pollen collected by honeybees is usually mixed with nectar or regurgitated honey in order to make it stick together and adhere to their hind legs. The resulting pollen pellets harvested from a bee colony are therefore usually sweet in taste. Certain pollen types however, are very rich in oils and stick together without nectar or honey. A foraging honeybee rarely collects both pollen and nectar from more than one species of flowers during one trip. Thus the resulting pollen pellet on its hind leg contains only one or very few pollen species. Accordingly, the pollen pellet has a typical colour, most frequently yellow, but red, purple, green, orange and a variety of other colours occur (see Figure 3.3).

The partially fermented pollen mixture stored in the honeybee combs, also referred to as "beebread" has a different composition and nutritional value than the field collected pollen pellets and is the food given to honeybee larvae and eaten by young worker bees to produce royal jelly. Saying pollen is the perfect food because it is the only food source for honeybees other than honey, their major carbohydrate source is not only based on a questionable comparison between human needs and bee requirements, but also on plain misinformation.

a) **b)**

Figure 3.2: a) A honeybee forager collecting pollen from a composite flower. The pollen grains caught in the specially branched hairs of honeybees are brushed off with the legs, moistened with nectar or honey and compacted in the pollen pellets on the outside of the hind legs (photo courtesy of F. Intoppa). b) A scanning electron microscopic enlargement of the hind leg of a honeybee with the pollen pellet on the outside (photo courtesy of R.C. Davis). The bottom section of the leg consists of the pollen brush. The joint between the leg segments serves to compact the pollen and push it to the outside, thus forming the typical pollen pellet.

3.2 Physical characteristics of pollen

Pollen grains range from 6 to 200 μ m in diameter, and all kinds of colours, shapes and surface structures may be observed. These are usually typical enough to allow species or at least genus identification (see Figures 3.3 and 3.4). Most pollen grains have a very hard outer shell (sporoderm) which is very difficult or impossible to digest. It is so durable that it can be found in fossil deposits millions of years old. There are, however, pores which allow germination and also extraction of the interior substances.

3.3 The composition of pollen

Since the composition of pollen changes from species to species, variation in absolute amounts of the different compounds can be very high. Protein contents of above 40% have been reported, but the typical range is 7.5 to 35%: typical sugar content ranges from 15 to 50% and starch content is very high (up to 18%) in some wind-pollinated grasses (Schmidt and Buchmann, 1992). Composition of pollen and bee-collected pollen however, has to be distinguished. Some average values for bee-collected pollen are shown in Table 3.1.

Figure 3.3: Different coloured pollen pellets collected byhoneybees

(Photo courtesy of F. Intoppa)

The major components are proteins and amino acid, lipids (fats, oils or their derivatives) and sugars. The minor components are more diverse (Table 3.2). All amino acids essential to humans (phenylalanine, leucine, valine, isoleucine, arginine, histidine, lysine, methionine, threonine and tryptophan) can be found in pollen and most others as well, with proline being the most abundant. Many enzymes (proteins) are also present but some, like glucose oxidase which is very important in honey. have been added by the bees. This enzyme is therefore more abundant in "beebread" than in fresh pollen pellets.

Only 16 of the 31 fatty acids found in pollen had been identified by 1989 (Shawer et al. 1987 and Muniategui et al., 1989). Palmitic acid is the most important one, followed by myristic, linoleic, oleic, linolenic, stearic acids etc. Simal et al., (1988) list 7 sterols, including cholesterol. Mono-, di- and triglycerides are fairly abundant, too.

Most simple sugars in pollen pellets such as fructose, glucose and sucrose come from the nectar or honey of the field forager. The polysaccharides like callose, pectin, cellulose, lignin sporopollenin and others are predominantly pollen components. After storage in the comb the further addition of sugars and enzymes creates beebread, through lactic acid fermentation.

Table 3.1:
The average composition of dried pollen

	Bee-collected		**Hand-collected**
	%[a]	%[b]	%[b]
Water (air-dried-pollen)	7	11	10
Crude protein	20	21	20
	3	3	4

Ash	3	3	4
Ether extracts (crude fat)	5	5	5
Carbohydrate			
Reducing sugars	36	26	3
Non-reducing sugars	1	3	8
Starch	-	3	8
Undetermined	28	29	43

[a] ***As reported by Tabio et al., 1988***

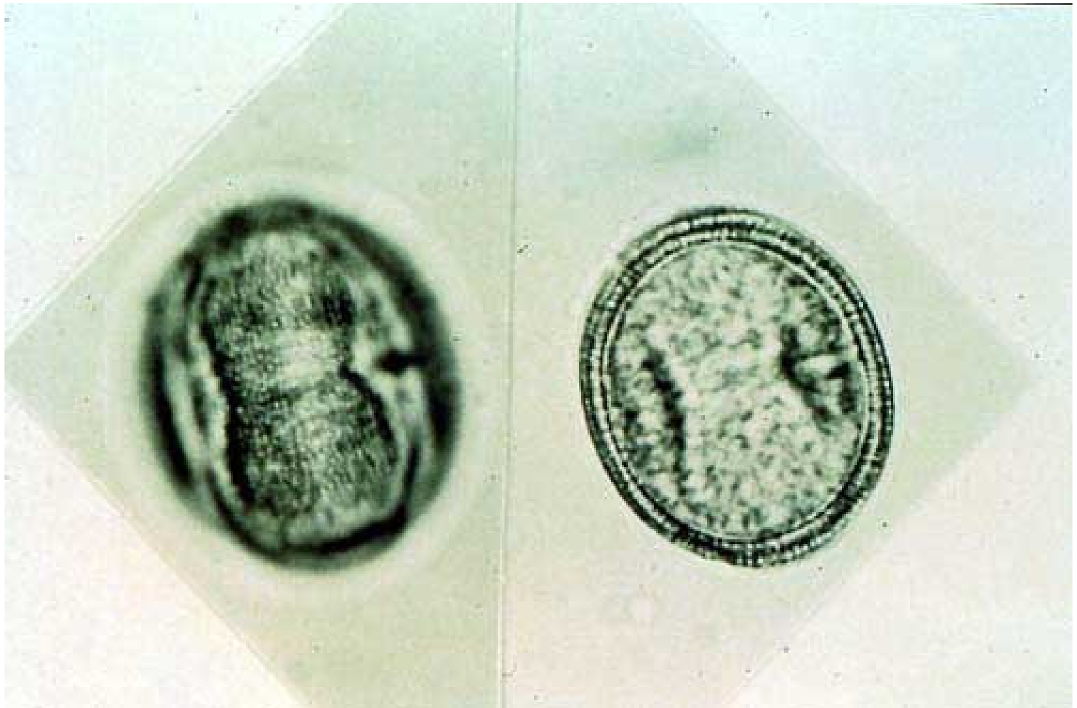
[b] ***As reported by Crane, 1990***

Table 3.2:
Minor components of bee collected pollen (Crane, 1990)

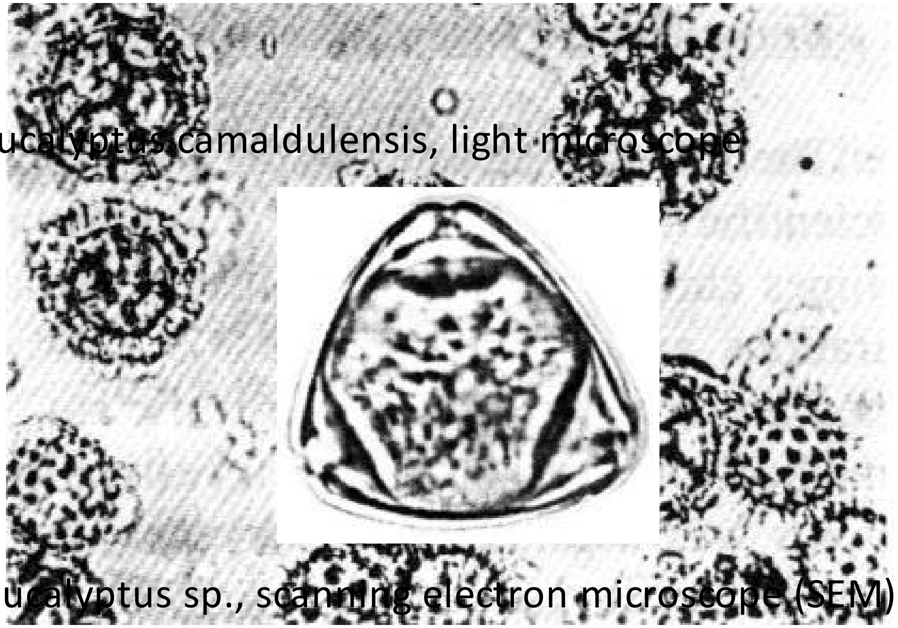
Flavonoids	At least 8 (flavonoid pattern is characteristic for each pollen type)
Carotenoids	At least 11
Vitamins	C, E, B complex (including, niacin, biotin, pantothenic acid, riboflavin (B_2), and pyridoxine (B_6)).
Minerals	Principal minerals: K, Na, Ca, Mg, P, S. Trace elements: A1, B, C1, Cu, I, Fe, Mn, Ni, Si, Ti and Zn
Terpenes	

Free animo acids	All
Nucleic acids and nucleosides	DNA, RNA and others
Enzymes	More than 100
Growth regulators	Auxins, brassins, gibberellines, kinins and growth inhibitors

a) Anarcadium sp. From honey in Guyana

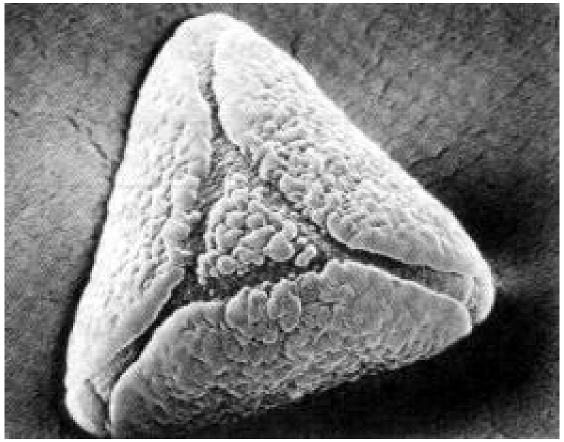


b) Vernonia perotteti gr. (large) and Synedrella gr (small, spiny) from honey in Malawi

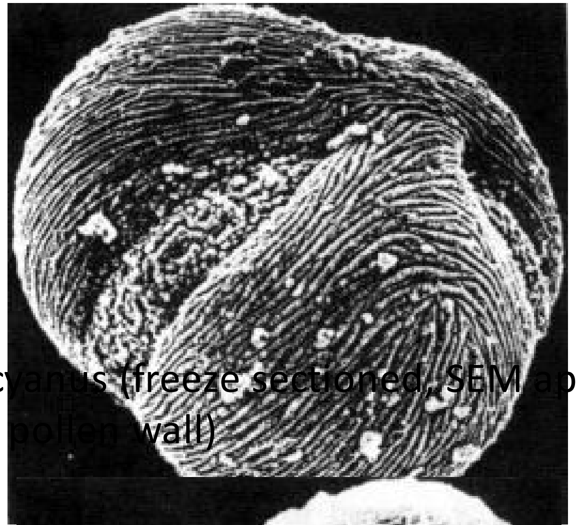


c) Eucalyptus camaldulensis, light microscope

d) Eucalyptus sp., scanning electron microscope (SEM)



e) Acerplantanoides (SEM, approx. 2600x)



f) Centaurea cyanus (freeze sectioned, SEM approx 2400x) showing thick pollen wall)

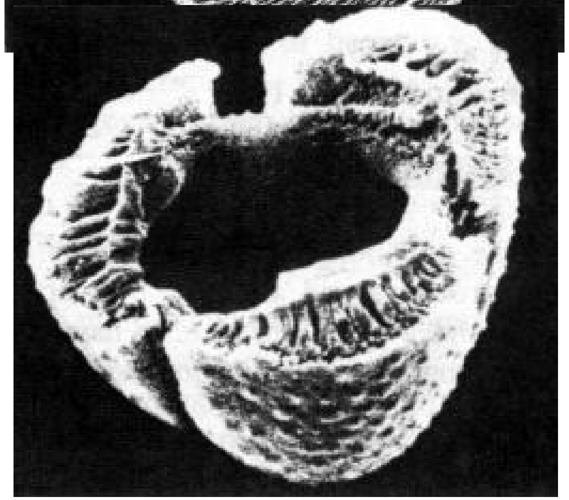


Figure 3.4: Pollen grains of various species. Photos courtesy of (a) L. Persano Oddo; (b and c) G. Ricciardelli d'Albore

from Persano Oddo et al., (1988); (d) F. Intoppa; (e and f) S. Nilsson from Nilsson et al., (1977).

3.4 The physiological effects of pollen

3.4.1 Unconfirmed circumstantial evidence

The effects and benefits derived from pollen consumption, according to some of the non-scientific literature on the subject are endless. Many people report improvement of sometimes chronic problems. Most of the major ailments reported to improve with pollen preparations are listed in Table 3.3. However, one should be aware that the benefits reported are not usually from scientific studies but are merely personal experiences without any medical or other scientific investigation of claims. Sometimes the disappearance of symptoms was witnessed by physicians, but the reasons for such cures were not confirmed through further investigations.

Table 3.3:
Non-scientific claims and reports of benefits, cures or improvements derived from the use or consumption of bee-collected pollen.

Improvements	Cures of benefits
Athletic preformance	Cancer in animals
Digestive assimilation	Colds
Rejuvenation	Acne
General vitality	Male sterilitya
Skin vitality	Anaemiab

Appetiteb	High blood pressureb
Haemoglobin contentb	Nervous and endocrine disordersb
Sexual prowess	Ulcers
Performances (of a race horse)	

[a] ***Ridi et al., 1960***

[b] ***Sharma and Singh, 1980***

3.4.2 Scientific evidence

The only long-term observations on the medicinal effect of pollen are related to prostate problems and allergies. Several decades of observations in Western European countries and a few clinical tests have shown pollen to be effective in treating prostate problems ranging from infections and swelling to cancer (Denis, 1966 and Ask-Upmark, 1967).

Supplementation of animal diets with pollen has shown positive weight gain and other beneficial effects for piglets, calves, broiler chickens and laboratory cultures of insect (see 3.5.2).

Certain bacteriostatic effects have been demonstrated (Chauvin et al, 1952) but this is attributed to the addition of glucose oxidase (the same enzyme responsible for most antibacterial action in honey) by the honeybee when it mixes regurgitated honey or nectar with the pollen (Dustmann and Gunst, 1982). Therefore, this activity varies between pollen pellets and is much higher in beebread. A very slight antibacterial effect can also be detected in pollen collected by hand (Lavie, 1968).

There is some evidence that ingested pollen can protect animals as well as humans against the adverse effects of x-ray radiation treatments (Wang et al., 1984; Hernuss et al., 1975, as cited in Schmidt and Buchmann, 1992).

3.5 The uses of pollen today

3.5.1 As medicine

In order to desensitize allergic patients, pollen is usually collected directly from the plants, to allow proper identification and purity. A pollen extract is then injected subcutaneously. Desensitization through ingestion of pollen is claimed, but has not received any scientific confirmation.

For treatment of various prostate problems, pollen is usually prescribed in its dry pellet form as collected by the bees. Pollen from different countries or regions seems to work equally well. However, pollen has not been officially recognized as a medicinal drug.

Since the consumption of pollen appears to improve the general condition and food conversion rate in animals as well as people, its support in accompanying other cures should be solicited more frequently. There may be other medicinal uses in traditional medicine which, however, have not been published in readily accessible journals.

3.5.2 As food

The major use of pollen today is as a food or, more correctly, as a food supplement (see Figure 3.5). As stated earlier its likely value as a food for humans is frequently overstated and has never been proven in controlled experiments. That it is not a perfect food, as stated on many advertisements, food packages and even in various non-scientific publications should be obvious. Its low content or absence of the fat soluble vitamins should be sufficient scientific evidence. This does not mean that its consumption may not be beneficial, as has been shown scientifically with various animal diets.

Pollen has been added to diets for domestic animals and laboratory insects resulting in improvements of health, growth and food conversion rates (Crane, 1990; Schmidt and Buchmann, 1992). Chickens exhibited improved food conversion efficiency with the addition of only 2.5% pollen to a balanced diet (Costantini & Ricciardelli d'Albore,

1971) as did piglets (Salajan, 1970). Beekeepers too, feed their colonies with pure pollen, pollen supplements or pollen substitutes (see 3.11.6) during periods with limited natural pollen sources. The relatively high cost of pollen suggests the need for a detailed feasibility analysis of pollen as food additive or supplement.

Only a good mixture of different species of pollen can provide the average values mentioned in the tables describing the composition of pollen. The real value of diversity of pollen content, however, lies in the balance of these nutrients and the synergistic effect of the diversity as well as more subtle effects or characteristics related to their origin rather than their quantitative presence. Those very subtle characteristics and sensitive compounds are easily lost with improper storage and processing, something to carefully watch when making or buying quality products containing "bee" pollen.

The stimulative effect of pollen and its possible improvement of food conversion in humans as well as animals, should be of particular interest to those who have an unbalanced or deficient diet. There are no hard scientific data to back up this information, but a detailed study might show tremendous potential benefit to a very large portion of human society. The only serious problem with incorporating pollen in foods like candy bars, sweets, desserts, breakfast cereals, tablets and even honey is the widespread allergic susceptibility of people to pollen from a wide variety of species (see 3.10).

Beebread

Traditional beekeeping cultures with honeybees or stingless bees, usually appreciate the stored pollen, i.e. beebread (see Figure 3.6). Its characteristic sour taste together with brood and honey is a delicacy consumed directly during harvesting. The pollen stored by honeybees undergoes a lactic acid fermentation and is thus preserved. This final storage product is called beebread. As also mentioned in Chapter 8, these beebread combs may be sold directly but a recipe in 3.12.2 describes the preparation of fermented pollen in a similar way. This improves the nutritional value of pollen and avoids the need for freezing.

Natural and homemade beebread will keep for a considerable time and can easily be transported to the market

and served - even in small quantities - as an excellent source of otherwise scarcely available nutrients. It can be sold clean and by itself or immersed in honey to make it more attractive in taste. Small pieces of comb can thus be sold or given away as candy.

The nutritional value of beebread is much higher in places where limited food variety or quantity create nutrient imbalances. It is particularly children who might benefit the most from regular pollen supplements in their diets.

3.5.3 In cosmetics

Pollen has only recently been included in some cosmetic preparations with claims of rejuvenating and nourishing effects for the skin. The effectiveness has not been proven, but there is a considerable allergy risk for a large percentage of the population. Therefore this practice is not very advisable since it excludes a large proportion of potential customers and puts others at risk of having or developing very unpleasant allergic reactions.

Including alcoholic or aqueous pollen extracts (see 3.11.1) in cosmetic formulations appears to cause no or only rare allergic reactions. While little is known about the effectiveness of such extracts, they are still the preferred method of preparation for formulations in the cosmetic industry.

Figure 3.6: Beebread, fermented pollen, is stored in open cells (lighter cells). Usually it is found near or on the brood combs, between honey and brood. Harvesting usually destroys the associated brood and comb.

3.5.4 For pollination

Hand and bee-collected pollen have been used for mechanical or hand pollination. The viability of hand-collected pollen can be maintained for a few weeks or months by frozen storage. Bee-collected pollen however, starts losing its viability after a few hours and increasingly with age. It is believed that some of the enzymes added by bees during foraging inhibit the pollen's ability to germinate on the flower stigma (Johansen, 1955, and Lukoschus and Keularts, 1968). Large-scale applications with mechanical dusters or by using dusted honeybees for dispersion were only moderately successful.

3.5.5 For pollution monitoring

Since the 1980's, experiments have shown that pollen collected by honeybees reflects environmental pollution levels when examined for metals, heavy metals and radioactivity, (Free et al., 1983; Crane, 1984 and Bromenshenk et al., 1985). Contaminants can be quantified and sampling may be cheaper than most standard methods currently in use. Attempts have also been made to use pollen-collecting honeybees for the identification of potential mining areas (Lilley, 1983). The same effect of accumulating aerial deposits and selective plant secretions of minerals beneficial when used to monitor pollution control becomes a hazard if pollen from heavily polluted areas is used for human or animal consumption.

3.6 Pollen collection

Extreme care should be taken that pollen is not contaminated by bees collecting from flowers treated with pesticides. During, and for several days or weeks after treatment of fields or forests in an area of several square kilometres (in a circle of at least 3-4 2 km diametre) around the apiary, no pollen should be collected. This is independent of the method of pesticide application. Even systemic pesticides have been shown to concentrate in pollen of, for example coconut (Rai et al., 1977). Since a pollen pellet is collected from many flowers, even small quantities of pesticides per flower can be accumulated rapidly to reach significant concentrations.

Though pollen pellets are collected before they enter the hive, treatment of colonies for bee diseases, can contaminate the pollen pellets. Though, for example, cleaning of debris from the hive and bees regurgitating syrup, nectar or honey during collection of the pellets.

Pollen pellets are removed from the bees before they enter the hive. There are many designs of pollen traps (see Figures 3.7 to 3.8) some easier to clean and harvest, others more efficient or easier to install. The efficiency rarely exceeds 50%, i.e. less than 50% of the returning foragers loose their pollen pellets. Bees are ingenious in finding ways to avoid losing their pellets, like small holes or uneven screens and may even rob pollen from the collecting trays, if access is possible. Under some circumstances, pollen collection methods and regimes may interfere with

normal colony growth or honey production. Therefore, standard beekeeping manuals should be consulted for the timing of collections (Dadant, 1992).

Pollen should be collected daily in humid climates but less frequently in drier climates. To avoid deterioration of the pollen and growth of bacteria, moulds and insect larvae, pollen should be dried quickly. Ants can remove considerable amounts from pollen traps. Krell (personal observations) reports that losses can be up to 30% in temperate climates.

Pollen needs to be dried to less than 10% moisture content (preferably 5 % or 8% according to some laws) as soon as possible after harvesting. A simple method uses a regular light bulb (wE and 1 1OV or 20W and 220V) suspended high enough above a pollen carton or tray so that the pollen does not heat to more than 40 or 45 ^{0}C. For solar drying, the pollen itself should be covered to avoid direct sunlight and overheating.

After drying, the pollen needs to be cleaned of all foreign matter. A tubular tumbler made out of a wire mash with a fan can clean considerable quantities of pollen pellets. Simpler winning methods can be used too. Benson (1984, in English) and Marcos (1991, in French) give very good accounts on trapping and subsequent processing of pollen.

Most types of pollen traps are currently only fitted to standard frame hives. are fitted to traditional log, clay or straw hives, small modifications are necessary.

Beebread is usually found on brood combs or combs near the brood nest. Available quantities are normally very small and inadvertently the brood comb and sometimes the whole colony are destroyed during harvest. A team of Russian scientists described a nondestructive means of extracting beebread from combs, harvesting 300-600 kg per year from 1500 colonies (Nakrashevich et al., 1988).

Some races of bees will store large quantities of beebread when colonies have become queenless, or the brood nest and/or plenty super space, are above an empty box with combs. Such manipulations will be more difficult or impossible with most traditional bee hives but modifications may be worthwhile. As mentioned earlier, beebread

can also be made at home from bee-collected pollen(see section 3.12.2).

Other social bees usually store their pollen in special containers separate from the brood combs. These "pollen pots" can therefore be harvested without destroying the nest, but caution is necessary not to deplete the food sources completely.

3.7 Pollen buying

Quality control of pollen is difficult and under most circumstances impossible. It is therefore very important that the buyer knows the supplier well and can trust him. A reliable supplier should have all necessary storage and processing facilities and use them. Furthermore the production area, not only the residence or processing centre, should be free of agrochemicals and industrial pollution (and chemical treatments of the colonies). There are less and less of these regions in industrialized countries and a vast array and quantity of agrochemicals are now being used even in developing countries. More remote zones have problems with proper storage and transport and may require special collection and storage centres.

a) **b)**

Figure 3.7: a) Pollen trap design to fit into a hive entrance between the bottom board and the brood chamber. b) The screen through which the bees have to pass can be made of a thick plastic sheet (at least 3 mm) with holes of 4.7 mm diameter for European honey bees and of 4.2 mm diameter for smaller bees such

as from African races. Two wire screens with holes of similar size can also be used, spaced 4 to 7 mm apart.

Sometimes, unethical, deceptive marketing or ignorance prevents consumers or buyers to be informed about the above conditions. Until reliable tests have been developed and legal requirements force more frequent testing only responsible producers can be relied upon.

Buying processed products requires similar caution. The processor has to use gentle processing procedures to maintain those subtle qualities of pollen, which earned it its collected during four days. This type of trap is placed between bottom board and brood reputation. The buyer, whether consumer, retailer or processor has to be very careful and pay considerable attention to all handling and processing from the field collection to the final product. A truthful label could describe all the essential steps taken in order to guarantee the quality of the product. The need for highly ethical behaviour and knowledge at all levels is a requirement to be considered seriously, by anyone starting in this business, be it producer, processor or distributor. Forming a self-controlling organization, which certifies and controls producers and manufacturers may be useful or necessary to minimise fraud or avoid unreliable quality.

Figure 3.8: Pollen tray of a modified OAC trap (Waller, 1980) with two types of pollen chamber permitting better ventilation and pollen removal without disturbance of the colony. Returning foragers are forced to crawl through a double screen of 5-mesh wire (5 wires per inch) with 4-7 mm distance between screens.

3.8 Storage

Pollen, like other protein rich foods, loses its nutritional value rapidly when stored incorrectly. Fresh pollen stored at room temperature loses its quality within a few days. Fresh pollen stored in a freezer loses much of its nutritive value after one year. Longer, improper storage leads to the loss of a few particular amino acids, which cause deficiencies in brood rearing (Dietz, 1975). When dried to less than 10% (preferably 5%) moisture content at less

than 45�C and stored out of direct sunlight, pollen can be kept at room temperature for a several months. The same pollen may be refrigerated at 5�C for at least a year or frozen to –15�C for many years without quality loss as tested by feeding to honeybee colonies and recording brood rearing rate (Dietz and Stephenson 1975 and 1980).

Since sunlight, i.e. UV radiation, destroys the nutrient value of pollen, other more subtle characteristics probably suffer worse damage. Storage of dry pollen in dark glass containers, or in dark cool places, is therefore a requirement.

3.9 Quality control

Only a few countries, such as Switzerland and Argentina, have legally recognized pollen as a food additive and established official quality standards and limits. Though sold in many health food stores, pollen is not considered an additive by the US FDA (Food and Drug Administration) and it does not have to comply with special standards. It is, however in the producer's own best interest to maintain the highest standards of cleanliness for his product.

The Argentinean standards require microbiological characteristics of not more than $1SOx1O^{0}$UFC/g aerobic microbes, $1O^{0}$UFC/g fungi and no pathologic microorganisms. The moisture content should not exceed 8% (controlled by vacuum drying at 45 mm Hg and 65^{0}C). Other limits include a pH of 4-6, protein content of 15-28% Kjeldahl (N x 6.25) of dry weight, total hydrocarbons of 45-55 % of dry weight and a maximum ash content of 4% of dry weight (determined at 600 ^{0}C).

Pollen used for cosmetic purposes should have the same, if not a better quality than that destined for consumption as food. The first quality control is assessment of gross contamination with foreign substances, i.e., parts of bee and hive debris. Further controls might include measurement of moisture content and a bacterial count. Determination of various agrochemicals, including drugs used inside bee colonies are possible and may be required in some circumstances. These analyses require sensitive, expensive chromatographic equipment.

Since air pollutants and agro-chemicals have been shown to accumulate in pollen collected by bees (see 3.5.5) pollen should originate from unpolluted areas with the lowest chance of contamination by agrochemicals, industrial pollutants and drugs applied by beekeepers. Producers from such areas should make particular note of this in their advertising.

Degradation of pollen nutrients by inadequate collection, drying and storage can only be tested by bioassay, i.e. feeding pollen to honeybee colonies and observing the quantity of brood reared, which is a very lengthy and laborious process. Therefore, only reliable primary products who have the required knowledge and facilities should be considered as supplies.

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3.10 Caution

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Pollen allergies, also called hay fever have been known for a long time but in today's stressful environment it seems that more and more people suffer from allergies. Often it is difficult to identify the exact source. Specific pollen allergies may be avoided by changing one's environment. Desensitization with established Western medical methods (subcutaneous injections of pollen extracts) are slow and generally have only a temporary effect, so they need to be repeated. Traditional and alternative health practitioners have claimed to cure pollen allergies. It is said that the consumption of locally produced honey has a desensitizing effect because all honeys contain small quantities of pollen. However, not all available pollen species are collected by bees and thus may not occur in the particular honey. There is not even anecdotal evidence that honey consumption will remedy pollen allergies, but consuming small quantities of honey regularly has not harmed anyone yet. The consumption of pressed honey which always has a very high pollen content, may at times cause small allergic reactions (personal experience) Feinberg et al., (1940) have shown in numerous comparisons that pollen consumption only marginally improved

allergic reactions, so marginally in fact that it cannot be recommended, nor can improvements be distinguished from improvements possibly due to general improvements in health.

The greatest risk of allergic reactions exists with the direct consumption of pollen. This, however, can be avoided by consuming pollen packed in capsules or coated pills which prevent direct contact with any mucous membranes. Once in the digestive tract, the body generally does not show any allergic reaction. Again, careful trials by sensitive individuals are recommended if consumption is assisted upon.

This preempts any foods in which pollen has been incorporated, but allows taking pollen for special health reasons. Barrionuevo (1983) and personal trials by the author, who is strongly allergic to some pollen species, confirmed that by avoiding contact with eyes, nose, mouth, throat and pharynx, no allergic reactions occurred with ingested pollen. Intestinal allergies to pollen are rarer than most food allergies (Schmidt and Buchmann, 1992). Still, careful trials by sensitive individuals are recommended for all products containing pollen.

Since there are so many different substances in the different pollen species to which people react with allergies, only some extractions or a general denaturalization can inactivate most of the allergens for commercial production. This probably ruins some of the beneficial characteristics of the pollen as well. Getting pollen from areas without the allergy-causing species may help individuals who want to consume pollen, but such identification and separation is unlikely to be feasible for commercial production.

A simple muscle resistance test (kinesiology) can show allergic sensitivities before actual contact with the substance occurs.

As a precaution, everybody, even those people who have not known any pollen allergies before, should first try very small quantities of the pollen or the product containing the pollen. Allergic reactions normally occur within a short period of time, from a few minutes to a few hours.

To avoid any problems with customers and with those who consume foods or use cosmetics and medicine-like products containing pollen, it would be advisable to include a warning on the product label, for example "This

product contains pollen which may cause allergic reactions. Try small quantities first".

Pollen should not be collected or purchased from areas with heavy industrial, urban or agricultural pollution (pesticide). The geographical origin of the pollen should be known, and producers as well as buyers and retailers should be using adequate cold storage.

3.11 Market Outlook

Dried pollen prices in the USA range from US$5 to 13 per kg wholesale and US$11 30 per kg retail (American Bee Journal, 1993). Encapsulated pollen or pollen tablets sell vials of 50 to 100 units and retail at prices of up to US$900/kg, at least in Italy and the

The bulk pollen consumer market seems to be growing in industrialized countries, but pollen tablets are still a common feature of health food stores and command an excessively high price. Encapsulation and extraction of pollen lend themselves easily to small scale manufacturing and result in safer consumer products.

Most of the buyers and large scale sellers of pollen are also honey traders. Crane (1990) however reports that a lot of commercial pollen is not bee collected, but machine-collected from certain wind pollinated plants which release very large quantities of dry pollen.

At least in industrialized countries and those with increasing numbers of health conscious consumers, pollen consumption is likely to increase further. It is difficult to see how wholesale prices of bulk pollen could drop much lower. On the other hand, there seems to be a wide market for reasonably priced, encapsulated pollen and tablets.

Promotion of pollen from uncontaminated, unpolluted or even tropical forest areas may find a small consumer base in importing countries.

The high nutritional value of pollen should find special consideration in rural communities. Though not a

traditional food, the ease of mixing it with other foods should facilitate acceptance. Rural hospitals could be the first to promote the use of pollen.

Figure 3.9 : Various commercial products containing bee-collected pollen in either a processed or unprocessed (from left to righ): liquid pollen extract, granola bar (musli), different coloured pollen pills and capsules and dried pollen.

3.12 Recipes

Pollen can be added to a variety of foods and snacks. It does not involve any special adaptation of recipes, because the pollen is usually added in small quantities. However, pollen has a distinct flavour of its own and is usually slightly sweet. Thus it will alter delicate flavours and can even be detected in products with stronger flavours such as chocolate bars or granolas. Quantities should therefore be adjusted according to flavour.

Considering the sensitivity of pollen, its inclusion in products requiring processing (particularly heating) may cause

a significant loss of beneficial effects. Fermentation into beebread may not only preserve many of the beneficial characteristics, but also add new enzymatic ingredients. Since pollen can easily be included in most recipes, only a few are provided here which might be marketable by small enterprises, including beekeepers. Various processed forms (encapsulated, pills, extracts) are presented (see Figure 3.9) and additional recipes can be found in Chapters 2, 5, 8 and 9.

3.12.1 Pollen extract

To avoid the granular structure of pollen or avoid some of the allergenic effects, pollen extracts can be prepared. The most common solvents for extraction are various types of alcohols. The higher the alcohol concentration, the more complete is the extraction of oils, fats, colours, resins and fat soluble vitamins from pollen. Solvents with lower concentration of alcohol mainly dissolve tannins, acids and carbohydrates. Therefore, with a variation of the alcohol concentration different types of extracts can be prepared. A propylene glycol extract contains most water soluble material, leaving behind the proteins, thus eliminating most if not all allergenic material. Such an extract is well suited for external applications such as in cosmetics. Oil extractions have been reported as inefficient. Treatment with diethylene glycol monomethyl ether discolours pollen and its extracts (D'Albert, 1956) where coloration may not be desired (cosmetics).

The following extract is prepared with a very high percent alcohol (95 % or more) to get most of the substances out of the pollen. The alcohol has to be food grade (fit for human consumption). Distilled beverages usually contain 40-60% alcohol or less, and so only produce less complete extracts.

A glass bottle or glazed clay pot is filled with 4 parts of 95% alcohol and 1 part of beebread (Dany, 1988). Bee-collected pollen can be used as well, but beebread has different (higher) nutritional values (see 3.12.2). Agitate the mixture at least once a day and leave it for 8 days. More frequent agitation improves extraction. The mixture is filtered through afine cotton cloth and stored in a dark glass bottle. It can be stored for a long time. The filtrate can again be washed in water and this weaker extract may be used immediately.

For further potentiation, 50 g of broken propolis can be added for extraction at the start. For medicinal purposes other herbal extracts can be added as well as mead, royal jelly etc.

A revitalizing concentrate, a teaspoon taken three times a day, is described (in parts by weight). Different proportions and additional ingredients are possible.

4	*Honey*	*4*	*Honey*
1	*Wheat germ (or wheat extract)*	*0.5*	*Pollen (or extract)*
1	*Pollen extract*	*0.5*	*Yeast (or stimulating plant extarct)*
1	*Dry yeast (brewers or bakers yeast)*	*0.05-0.5*	*Royal jelly*
0.1-0.4	*Royal jelly*		

3.12.2 Beebread (after Dany, 1988)

Normally, the term beebread refers to the pollen stored by the bees in their combs. The beebread has already been processed by the bees for storage with the addition of various enzymes and honey, which subsequently ferments. This type of lactic acid fermentation is similar to that in yoghurts (and other fermented milk products) and renders the end product more digestible and enriched with new nutrients. One advantage is almost unlimited storability of beebread in comparison with dried or frozen pollen in which nutritional values are rapidly lost. The natural process carried out by the bees can more or less be repeated artificially with dry or fresh bee-collected pollen. It is important however, to provide the correct conditions during the fermentation process.

The container

Wide-mouthed bottles or jars with airtight lids are absolutely essential. Airtight stainless steel or glazed clay pots can also be used. Containers should always be large enough to leave enough airspace (20 to 25 % of the total volume) above the culture.

The temperature

The temperature for the first two to three days should be between 28 and 32^{0}C; the bees maintain a temperature of approximately 34�C. After the first two or three days the temperature should be lowered to 20�C.

The high initial temperature is important to stop the growth of undesirable bacteria as quickly as possible. At this ideal temperature all bacteria grow fast so that an excess of gas and acid accumulates. Only lactic acid producing bacteria (lactobacilli) and some yeasts continue to grow. The former soon dominate the whole culture. This final growth of lactobacilli should proceed slowly, hence the reduction in temperature after 2-3 days.

The starter culture

It is best to start the culture with an inoculation of the right bacteria such as Lactobacillus xylosus or lactobacilli contained in whey. Freeze-dried bacteria are best if they can be purchased, but otherwise, the best cultures are those that can be obtained from dairies. Whey itself can be used. If the whey is derived from unprocessed fresh milk it should be boiled before use. A culture can also be started with natural beebread.

Preservation

Fermentation produces a pleasant degree of acidity (ideally pH 3.6-3.8). Some pollen species may promote excessive yeast growth but this does not spoil the beebread. If the flavour is strange or some other mildew-like or unpleasant odours arise from the beebread, discard it and try again. The final product, can be stored for years, once unsealed, it can be dried and thus is storable for many more months.

General conditions

For successful fermentation, exact quantities are less important than the correct conditions:

- the pollen to be fermented needs to be maintained under pressure
- the air space above the food needs to be sufficient (20-25 % of total volume)
- the container needs to be airtight
- the temperature should not drop below 18�C

Ingredients (in parts by weight):

10	*Pollen*
1.5	*Honey*
2.5	*Clean water*
0.02	*Whey or very small quantity of dried lactic acid bacteria*

Clean and slightly dry the fresh pollen. If dried pollen is used, an extra 0.5 parts of water is added and the final mix soaked for a couple of hours before placing it in the fermentation vessels. If the mixture is too dry, a little more honey-water solution can be added.

Heat the water, stir in the honey and boil for at least 5 minutes. Do not allow the mix to boil over. Let the mix cool. When the temperature is approximately 30-32 ^{0}C, stir in the whey or starter culture and add the pollen. Press into the fermentation container.

When preparing large quantities in large containers, the pollen mass should be weighted down with a couple of

weights (clean stones) on a very clean board.

Close the container well and place in a warm place (30-32 ^{0}C).

After 2-3 days, remove to a cool area (preferably at 20^{0}C). 8 to 12 days later the fermentation will have passed its peak and the beebread should be ready. The lower the temperature, the slower is the progress of fermentation. Leave the jars sealed for storage.

3.12.3 Honev with pollen

Health food stores and beekeepers sometimes add up to 5 % (by weight) of pollen to honey. Using fresh pollen may lead to fermentation of the honey. Very well dried and finely ground pollen, however is more difficult to mix into the honey. Mix the pollen with a smaller quantity of honey and then add it to the final batch.

No matter how well the powdered pollen pellets are mixed into the honey, the pollen will separate and rise to the top of the honey in a very short time. This does not look very attractive but people will be more inclined to buy the product if the cause is explained properly on the label. This is a more palatable way to eat pollen than eating the dry pellets directly and appears to preserve the delicate characteristics of pollen very well. One way to avoid separation is to mix the pollen with creamed or crystallized honey (see recipes in Chapter 2).

The most likely customers for such products are people who are more knowledgeable and very health conscious. Therefore, other bee products such as royal jelly or propolis can be added to the honey mixture and a still better price may be obtained. How much this improves the health or nutritional value of the honey mix remains unanswered. Since honey improves the uptake of several nutrients, it may benefit the absorption of other substances as well. The resulting product should have a fairly long shelf life, but particularly if royal jelly is added, the product should be refrigerated.

3.12.4 Granola or breakfast cereals

Dry pollen pellets can be sprinkled directly over a prepared breakfast or incorporated in a cereal. Most prepared cereals require baking during processing or heating prior to eating, either would reduce the beneficial characteristics of pollen.

In order to be included in granola, pollen pellets need to be pulverized and then sprinkled over the cooling cereal (granola) while it is still moist and sticky. Inclusion in the granola dough prior to baking is not recommended.

Pulverized pollen pellets may be mixed dry with powdery breakfast cereals or sprayed onto the cereal together with a honey (sugar) syrup possibly including other flavours or fruit juice after roasting or baking of the cereal.

An alternative for baked granolas as well as dry cereals (muesli) would be to include one or more measured portions of dried pollen pellets in a separate bag, ready to be added by the consumer. This avoids problems for some allergic consumers, saves processing and preserves the beneficial characteristics of pollen.

Granola

A basic granola recipe requires:

One or more of the rolled or puffed grains (rye, wheat, barley, buckwheat, oat, rice or some of the local grains still grown in many parts of the world), heated vegetable oil and a variety of seeds, nuts, dried fruits, coconut, wheat germ, etc., shredded or finely chopped and added in proportions determined by the preference of the manufacturer or customer.

Dried milk powder can be added and dried fruits, fruit juice or honey can be used for sweetening. Any pollen or insect larvae should only be added after toasting.

The rolled grains are spread in a baking pan and toasted under fre quent stirring for 10 to 15 minutes in an oven heated to 150^{0}C. Then the rest of the ingredients are added and toasted for another 15 minutes with more stirring. A simpler alternative which however reduces the nutrient value of some of the ingredients involves

mixing all the ingredients together and toasting them - also at 150 ^{0}C - for 35 minutes. Once cooled, store tightly covered and preferably refrigerated.

A muesli or dry cereal usually consists only of dried ingredients. No toasting or baking is necessary. The same granola ingredients can be mixed but without the oil. For consumption, the muesli is mixed with cold milk, water or fruit juice. Alternatively, it may be briefly boiled to soften the rolled grains.

Granola bars

To make granola bars, the same granola mixture should be pressed into the preferred shape after the first toasting. The second toasting is then completed at a slightly lower temperature and over a longer period of time. If sufficient honey is used, the hot mixture can be pressed into oiled forms also just before the toasting is finished, when the granola is still moist and sticky.

The sample recipe below is adapted from "The Joy of Cooking" (Rombauer and Rombauer Becker, 1975):

Ingredients (in parts by volume, e.g. cups):

2	*Rolled oats*	*1*	*Dry milk*
2	*Rolled rye or barley*	*2*	*Coarsely chopped almonds*
2	*Wheat or corn flakes (or rolled)*	*2*	*Shredded or flaked coconuts*
1	*Vegetable oil*	*2*	*Hulled sunflower seeds*
1	*Honey*	*1*	*Sesame seeds*
3	*Wheat germ*	*q.s.*	*Pollen, insect larvae or dried fruits*

Preheat the oven to 150 ^{0}C. Scatter the rolled grains on a baking sheet or pan and toast for 15 minutes in the oven, stirring frequently. Slowly heat the oil and honey and add the remaining ingredients. Then combine with the toasted grains and spread thinly in the pan, continuing to toast in the oven and stirring frequently for another 15 minutes or until the ingredients are toasted. While the ingredients are still warm and sticky, sprinkle the pollen pellets, pollen powder, insect larvae or chopped dried fruits onto the granola and form into bars of the desired size.

3.12.5 Candy bars

There are many ways of preparing candy bars with nuts, chocolate, grains, popcorn and puffed rice to which pollen or even larvae can be added For replacing part of the sugars with honey in any recipe see the recipe section in Chapter 2.

The following is a general recipe from the same source as the granola and can be modified substantially for different flavours, textures etc.

Ingredients (in parts by volume):

3	*Honey*
4	*Butter*
0.3	*Water*
4 to 6	*Slivered almonds (or other nuts, larvae or pollen)*
3	*Melted semisweet chocolate*
1	*Finely chopped nuts, larvae, pollen or raisins*

Sliver or break large nuts such as almonds, hazelnuts and brazil nuts but, peanuts, for example, can be left whole. If a roasted nut flavour is preferred, add the nuts at the beginning to the honey, butter and water mix. If not, spread them on a buttered slab or pan and pour the cooked syrup over them.

Heat the honey, butter and water in a heavy skillet. Cook rapidly and stir constantly for about 10 minutes or until the mixture reaches the hard-crack stage (150 ^{0}C). Add the nuts and larvae quickly and pour into a buttered pan or slab or pour the syrup over the nuts on a buttered slab. When almost cool, sprinkle with pollen powder (or crushed pollen pellets) and brush with the melted chocolate. Before the chocolate hardens, dust with the finely chopped nuts, larvae or pollen. After cooling, break into pieces and wrap individually.

In order to form even-sized bars or round shapes, pour the syrup into buttered moulds. Before completely cooled, these bars can be dipped in melted chocolate and sprinkled with any of the above materials for decoration. For special care with chocolate coatings, see also recipes in Chapter 2.

Many regions have their own special and preferred sweets and candy bars. Pollen can be incorporated into many of these recipes. Such incorporations should take place towards the end of processing, and the first cooling phase, in order to preserve as much as possible of the subtle characteristics and benefits of the pollen.

Cereal-fruit bar

The following two recipes (adapted from Dany, 1988) preserve all the nutritious values which might otherwise be destroyed through heating in the previous preparations. The baking described in the granola and candy bar recipes is replaced by drying at temperatures of 40 to 45 ^{0}C. This also facilitates processing for those who do not have access to baking stoves.

The oats used here can be replaced by one or a mixture of other grains. They should however be rolled into flakes.

The pollen extract (3.12.1) mentioned here, can also be powdered, bee-collected pollen or the fermented manmade beebread mentioned in section 3.12.2.

Basic Ingredients (in parts by volume):

4	*Rolled oats*
1	*Boiled water or fruit juice*
0.2	*Vegetable oil or fat*
0.2	*Dry yeast (brewers yeast, bakers yeast or other)*
0.6-1.2	*Pollen extract*
q.s.	*Salt*

The following ingredients (by piece per 50 g. of oats) can be mixed according to taste and availability:

2	*Figs*	*Or*	*1 tablesp*	*Chopped chocolate*
�	*Banana*		*4*	*Dried apricots*
�	*Apple*		�	*Apple*
2 teasp	*Ground almonds*		*1 tablesp*	*Soybeans (toasted or boiled)*
1 tablesp	*Sunflower seeds*		*1*	

1 tablesp	*Raisins*	*1 tablesp*	*Raisins*
5	*Dates*	*1 tablesp*	*Chopped nuts*

A small amount of honey can be added for sweetening.

For a more unusual flavour the following is recommended:

50 g	*Rolled oats*
30 g	*Fresh pureed tomatoes*
1-2 tblsp	*Pollen extract*
�	*A pureed green pepper*
�	*Finely chopped onion*
1	*Clove of garlic*
s.q.	*Small quantities of herbal spices: estragon, thyme, rosemary, marjoram, oregano or chili pepper (according to taste)*

The pollen extract is dissolved in the water or fruit juice and the liquid poured over the rolled grains. Stir and leave for a while to allow absorption of the liquid, then add the other ingredients, mix and knead well and if necessary add a little water.

Spread the dough to dry on an oiled slab, board or sheet, to a thickness of 1 cm or less. Wax paper or a food grade plastic foil may also be used instead of the oiled slab. The thinner the dough is spread, the better the drying. Precut the dough into bars with a knife

Drying:

Slow drying at low temperatures is recommended. In a warm room, in an opened solar drier or in the direct sun, the mixture should be covered with a cloth to exclude flies, bees, dust and other contaminations. In an oven, the temperature should not exceed 50 ^{0}C with a door left partly open.

The fruit and nut mixtures will keep for a couple of weeks but the vegetable mixture should be consumed as soon as possible. Individual bars can be wrapped in waxed paper or plastic foil approved for food use.

3.12.6 Pollen supplements and substitutes in beekeeping

Haydak (1967) successfully tested a soybean flour, dried brewer's yeast and dry skimmed milk mixture in the proportions of 3:1:1. As a pollen substitute fed to honeybee colonies during a period of shortage, the mixture stimulated early colony development and overcame pesticide damage. One kilogramme of this substitute should be mixed with 2 litres of a concentrated sugar syrup in order to make it attractive to the bees. The sugar syrup is mixed in proportions of 2 parts granulated sugar with 1 part of hot water. A few egg yolks can be added as well and the mixture should be left standing overnight. The final consistency should be such that the paste stays on top of the frames, preferably wrapped in wax paper to prevent it from drying out.

Pollen supplements can be mixed from dried bee-collected pollen and various types of sugar syrup. However, the nutritional value of pollen (as larval food) deteriorates with time and under certain storage conditions as described in section 3.8. A more detailed discussion on this subject can be found in Dietz (1975).

3.12.7 Cosmetics

The claims attributed to the cosmetic effects of pollen have not been proven nor do pollen-based products seem to outperform alternative non-allergenic products. Given the risk to a growing percentage of allergic customers, it is not possible to recommend use of pollen in commercial products. If one wants to include pollen in personal cosmetics, the pollen pellets should be well dried and carefully ground to a very fine powder. They are likely to remain slightly abrasive, but can be ground further. The powder is mixed without heating at 1 % or less into any preferred preparation. Some alcoholic extracts, appear to cause no allergic reactions. Unfortunately, nothing is known about their effectiveness. For recipes see Chapter 9.

3.12.8 Pills and capsules

The best profit margin for selling pollen appears to be in selling it pill form. As mentioned earlier, the value of 1 kg of pollen pills or capsules can reach US$900 as compared to US$1 11-30 for 1 kg of dried pollen in the same stores. This enormous price margin cannot be achieved everywhere, but reflects a consumer attitude that exists in some countries.

In order to process pollen into pills a simple machine is necessary, which even second hand may cost a few thousand dollars. A paste of pollen and honey is prepared for pressing. No additives are necessary but gum arabic or a little pulverized wax can be incorporated. Coating the pills with wax render them non-allergenic, i.e. preventing contact with mucous membranes. If no pill press is available, more gum arabic or other gel and wax mixtures should then be used so that pills can be formed individually (see also 5.16.5).

For small enterprises, a more economical and feasible way of marketing dried pollen pellets for human consumption is by encapsulation. Gelatine capsules of 0 or 00 size are filled with the dried pollen. If the filling is conducted carefully, little or no pollen should be left on the outside, where it could cause harm. Extra cleaning may be required and a warning about possible allergic reactions should be printed on the label.

There are small, manually operated capsule fillers available for just a few dollars. Medium-size machines, which can fill 500 to 1000 capsules per hour can be made by a precision workshop (see Figure 3.10 and Annex 2). Bigger

machines handling up to 10,000 capsules per hour are available for large scale production. Pollen can be encapsulated dry in its original pellet form, as a ground powder, a honey/pollen paste, or in combination with other products particularly honey (for longer preservation) but also with propolis and royal jelly. Capsules should be stored in well sealed glass or plastic bottles. They should preferably be refrigerated and consumed within 180 days. Frozen storage and the use of higher proportions of honey or propolis will significantly prolong the useful storage life.

a)

b)

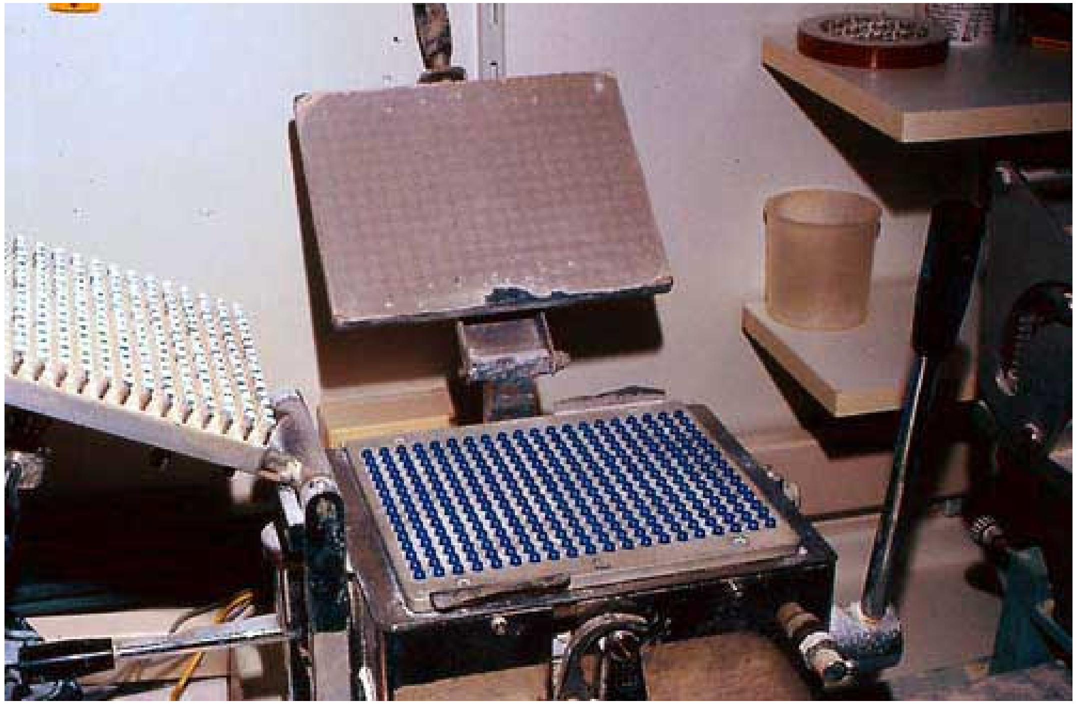

Figure 3.10: Medium-size hand-operated capsule filler. a) One machine separates the capsule halves, sorts and places them into separate trays. b) A second machine allows filling of capsule halves in presorted trays from a) and then closes the capsules. Using both machines, 1500-4 000 capsules can be filled, compacted and closed per hour by one person.

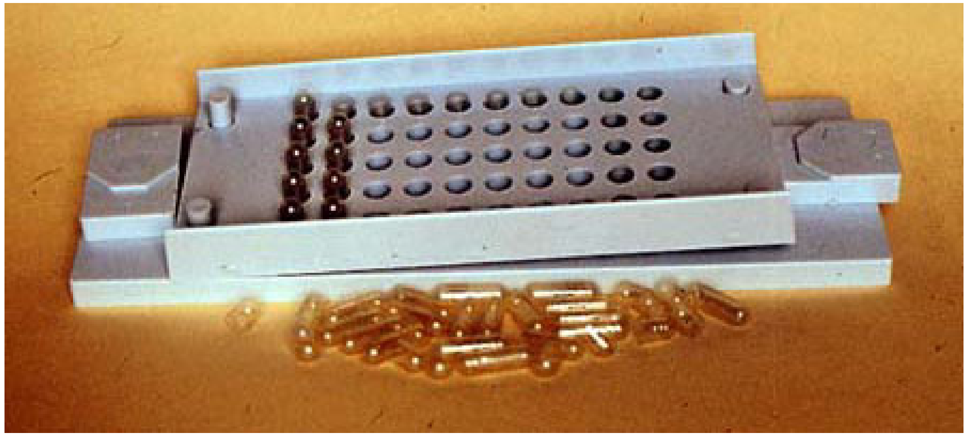

Figure 3.11: A small and cheap device for manually filling small quantities of hard gelatin capsules. With the top piece raised, as on the right, the pollen is brushed into the capsules. Once the top piece is lowered, as on the left side, the capsules can be closed.

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