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The world of wax

With a global trend towards natural fats and waxes, Dr Madelyn Bekker explains the economic significance, general chemical composition, production processes, applications and typical properties of the most important natural waxes

There is a worldwide trend towards natural fats and waxes as a renewable resource due to environmental concerns and the availability and cost of paraffin wax.

Natural waxes have a wide range of applications and the magnitude of annual worldwide wax consumption is reflected in these statistics:

- Paraffin waxes: (including microcrystalline waxes) 3M tonnes/year
- Polyolefin waxes: 200,000 tonnes/year
- Fischer-Tropsch (FT) wax: 100,000 tonnes/ year
- Montan wax: 50,000 tonnes/year
- Carnauba wax: 15,000 tonnes/year
- Beeswax: 10,000 tonnes/year
- Candelilla: 1,000 tonnes/year
- Other vegetable waxes: 2,000 tonnes/year

Carnauba and Candelilla wax are the most important and most widely used vegetable waxes. Beeswax is the most important animal wax.

Composition of wax

The chemical composition of most natural wax consists of, among others, triglycerides and carbon acids, such as stearic acid, oleic acid and palmitic acid. The functional acid groups of triglycerides are blocked and they are therefore less reactive than free fatty acids.

Some waxes can be made simply by hydrogenating appropriate oils and fats. Hydrogenation reduces the degree of unsaturation in the fatty acid groups and is a catalytic process whereby the number of double bonds are reduced and isomerisation of the residual fatty acids is promoted. Liquid oils with unsaturated glycerides are transformed into fats containing a higher percentage of saturated triglycerides. Hydrogenation is often called hardening of oils and soft fats. Hardened fats contain small amounts of free fatty acids and therefore colour pigments and additives are more stable in hardened fats. Non-hardened fats contain larger amounts of free fatty acids that are more reactive than glycerin esters (fats).

Palm wax

Palm oil is one of the most widely consumed edible oils in the world today. The oil palm produces fruit which consist of a hard kernel inside a shell, which is surrounded by a fleshy mesocarp.

Palm kernel oil is yellowish in colour and has a fatty acid composition different from that of palm oil. Palm kernel oil contains mainly lauric acid and more than 80% saturated fatty acids. Palm kernel oil closely resembles coconut oil in its fatty acid formulation and characteristics and therefore is a cost effective substitute for coconut oil in the production of quality soap.

Due to its environmentally friendly attributes, palm oil wax offers marketability as a sustainable or renewable resource. Palm oil is semi-solid at room temperature; a characteristic brought about by its 50% saturation level. The palm fruits are harvested and sent to palm oil mills to undergo sterilisation, bunch stripping, oil extraction, oil clarification and purification.

This crude palm oil then becomes the raw material for palm oil refineries where it is further processed by neutralisation, bleaching and deodorisation. The refined, bleached and deodorised (RBD) palm oil then undergoes fractionation by which RBD palm olein and RDB palm stearin are produced and these, in turn, can be further fractionated to obtain specialised products such as cooking oil, cooking fats, margarines (domestic and commercial), cocoa butter substitutes and creamers. ▶

FIGURE 1: PROPERTIES OF DIFFERENT TYPES OF WAX

Wax types	Congealing point (°C)	Drop melting point (°C)	Penetration 25°C (0.1 mm)	Oil content (mass %)	Colour (ASTM)	Acid Value (mg KOH/g)
Palm	44.0-48.0	57.0-61.0	5.0-22.0	1.0-9.0	0.2-0.7	1.0-4.0
Carnauba	80.0-86.0	82.0-86.0	<1	3.0-5.0	5.0-8.0	2.0-10.0
Candelilla	68.0-70.0	68.5-72.5	1.0-5.0	N/A	>8	12.0-22.0
Soya	N/A	51.0-55.0	40.0-50.0	N/A	1.0 Red Max	5.0-10.0
Sunflower	74.0-77.0	67.0-72.0	50.0-55.0	60	7.3	5.0-10.0
Tallow	55.0-60.0	64	10.0-12.0	3.0-4.0	0	210
Beeswax	62.0-65.0	N/A	15.0-20.0	N/A	0-2.5	17.0-24.0

Palm olein is the liquid fraction obtained by fractionation of palm oil. The physical characteristics of palm olein is different from those of palm oil as it is fully liquid in warm climate and has a narrow range of glycerides. Palm olein is widely used as cooking oil due to its good resistance to oxidation and formation of breakdown products at frying temperatures and longer shelf life of finished products. Palm stearin is the paste obtained by the fractionation of palm oil. Palm stearin is cheaper than palm olein and the physical characteristics of palm stearin differ significantly from those of palm oil and it is available in a wider range of melting points and iodine values.

Palm kernel oil is obtained from the kernel of the oil palm fruit. Palm kernel olein is the liquid component of palm kernel oil obtained from fractionation. Palm kernel stearin is the solid fraction of palm kernel oil obtained from fractionation. Palm kernel oil, palm kernel olein and palm kernel stearin find uses in margarine, confectioneries, coffee whitener, filled milk, biscuit cream and coating fats; with little or no further processing. There is a growing trend to use palm kernel oil products as an ingredient in the production of non-hydrogenated *trans*-fat free margarine.

Depending on the price, palm wax can be obtained from the hydrogenation of palm oil, palm stearin, palm kernel oil or palm kernel olein. The degree of unsaturation in the fatty acid groups of the oil is reduced. Liquid palm oil with unsaturated fatty acids are thus transformed into palm fat containing a higher percentage of saturated triglycerides.

About 25% of the palm fat available is used for non-edible products which include agricultural emulsifiers, stabilisers in PVC and paper manufacturing, a range of soaps, detergents and toiletries, pharmaceuticals, rubber, solvents, leather and candle making wax. Palm wax is very suitable to candle applications as it resists melting in hot summer months, has high contraction (making de-molding easier), takes colours easily and holds fragrance well. The palm wax candle also releases the scent throughout the entire candle and the scent of a palm wax candle does not fade away. Pure palm wax burns at a cooler temperature (about 2°C less) and at a slower rate than paraffin waxes. Palm wax candles have approximately 45% longer burn time as compared to the usual sized paraffin wax candle and the paraffin candle flame size is approximately 10mm higher than a pure palm wax candle. Pure palm candles also do not deform after three hours of burning; compared to a paraffin candle that shows signs of deformation at the top. Palm wax can be easily manipulated to produce an infinite array of surface patterns ranging from complex crystalline designs to smooth solid colours.

Paraffin waxes contain macro- and micro-crystalline components. The crystal structure of palm wax is different from paraffin wax as it forms a pure micro-crystalline structure that is so fine that light does not penetrate the pure palm candle.

The more palm wax a candle contains, the more dye is required to give colour strength. Palm wax influences dye colour stability (free fatty acids change colour in sunlight). The reactive functional acid groups accelerate the decaying of dyes.

Carnauba wax

Carnauba wax is by far the most important vegetable wax. Carnauba wax is obtained from the leaves of a palm tree known as *Copernica Cerifera*, which is also referred to as the "Tree of Life". This slow-growing Carnauba palm flourishes in the north-eastern regions of Brazil. The majority of tree harvesting takes place in the Brazilian states of Ceara and Piaui. The fan-shaped leaves are covered with wax to prevent dehydration in the equatorial climate.

The production process of cutting of the leaves and sprouts takes place during the dry months of September to February, with workers using knives on long poles to trim the leaves from mature trees. The cut leaves are sun-dried and mechanically thrashed to remove the crude wax. The wax is then melted over water. Carnauba wax is therefore non-hardened (non-hydrogenated) wax. The dried leaves are also chopped and chips removed to give a mixture of 60% wax and 40% leaves. The annual yield of wax is 150g/palm. The colour and quality of the wax are governed by the age of the leaves. The unopened heart leaves have light coloured wax (prime yellow) and the outer palm leaves wax is yellow, grey-green or grey-brown depending on the climatic condition during vegetation. Carnauba is one of the hardest and highest melting natural waxes. It has a fine crystalline structure and a weakly aromatic odour and characteristic hay-like smell in the molten state.

Carnauba is used in cosmetics, pharmaceuticals, candles, polishes, the food sector, polymer processing, inks, paper coatings and fruit coatings.

Candelilla wax

The Candelilla plant (*Euphorbia Antisyphillitica* and *Pedilanthus Pavonis*) grows in Northeastern Mexico in the wilds of the north central plains and foothills of the Chihuahua Desert, a semi-arid area of more than 100,000km^2.

Candelilla wax is fundamentally different from Carnauba wax in its high hydrocarbon content of 45% and resin content of 20%. The typical chemical composition of Candelilla is 42% hydrocarbons (90% paraffins and 2% alkenes), 39% wax, resin and sitosteroyl esters, 6% lactones, 8% free wax and resin acids, and 5% free wax and resin alcohols.

As in all natural waxes, in Candelilla wax, the wax acids or alcohols with even-numbered carbon chains have typical and distinctive chain length distributions.

The production of Candelilla wax is confined to areas where rugged climatic and topographical conditions combine to produce the highest wax-yielding varieties. Plants growing in the hottest and driest areas produce a scale-like covering on the plant which, after processing at hundreds of rural sites, yields a hard, brittle wax. Plant material is boiled with 0.2% sulphuric acid in open vessels. The wax is skimmed off into barrels. Yields based on plant material are 3-4%. Candellila wax is therefore non-hardened (non-hydrogenated) wax and would contain more free fatty acids.

Candelilla is used in cosmetics, polishes, pharmaceuticals, precision casting, lubricants, adhesives, paper coatings and sizing, chewing gum base, electric insulators and candle compositions.

PALM OIL WAX OFFERS MARKETABILITY AS A SUSTAINABLE OR RENEWABLE RESOURCE