



International Development Research Centre  
Centre de recherches pour le développement international

## **Carmine Extraction Technology**

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## **IDRC Carmine Extraction Process**

During 1989 - 1990, IDRC sponsored collaborative work between ITINTEC ( Peru ) and Simon Fraser University ( B. C. ) to develop a process flow sheet and pilot plant for the extraction of carmine, the complex Al / Ca chelate of carminic acid, from dried cochineal. The extraction process so developed has been shown to yield 70- 80% of the carminic acid contained in the dried cochineal feedstock, producing an aluminium/calcium lake salt (carmine) containing 65% by weight carminic acid. This was considered a premium product compared to the then existing industry standard of 52 - 55% contained carminic acid in commercial carmine. These results were subsequently confirmed 1991- 1993 in further IDRC sponsored work performed by CODETEC (Brazil), who extended the scope of the R&D somewhat by conducting bench-scale tests on the extraction of carminic acid and a water soluble variant of carmine lake. Both organisations, ITINTEC and CODETEC, generated business projections for a green-field plant rated at ~1000 kg/ month carmine production capacity. Of the overall project activity, only the portion related to carmine lake powder production is discussed here. The IDRC carmine extraction process follows:

The first step is to **SIEVE** the dried # 1 grade cochineal to remove the finer particulate material (lower carminic acid content). Only material retained on a #10 - #14 sieve is processed, with the reject material being set aside for modified secondary treatment. The coarse fraction of the retained raw material is then **DEGREASED** with an organic solvent ( e.g., hexane ) to remove waxes and grease from dried body parts, and the cleaned and dried feedstock is then **MILLED** to -100 mesh sieve size to break down the tissues containing the colorant, and so accelerate the **EXTRACTION** phase and maximise carminic acid dissolution and recovery. The ground cochineal is fed into a stainless steel reactor containing boiling alkaline water, i.e., a solution of sodium carbonate at pH 9, steam heated to 95-100 C, using a batch loading rate of 20-25 gm cochineal / litre. Vigorous mechanical stirring of the closed reactor contents during the entire 15 to 30 min. treatment period is critical to ensure maximum extraction of the carminic acid. Recovery levels range from 70 to 80 % of the carminic acid in the feedstock. The boiled carminic acid solution is then filtered in situ by adding a flocculent to help reduce turbidity by passing or pressing the alkaline liquor through a 120 mesh sieve to retain the solid cochineal residue.

**PRECIPITATION** of carmine from the hot solution is then achieved by reducing the pH to 5.5 - 5.0 by adding citric acid; simultaneously adding appropriate amounts of aluminium (alum) and calcium ( chloride ) salts; boiling the treated liquor at 100 C for 15-20 min., during which time the Al /Ca salt of carminic acid precipitates from solution. Next, **SEDIMENTATION** of the carmine occurs by gravity over a period of 1-2 hours, following which the mother liquor is drained and the wet sediment transferred to a separate unit for disc **CENTRIFUGATION**. The time dependent stages, from extraction through centrifugation, dictate batch cycle times for these steps in the range of 4-6 hours, depending on the volume of throughput.

The resultant carmine deposit is cleaned by **WASHING** with de-ionised water to remove any soluble impurities carried over from the reactor. The washed product is **STERILISED** at 120 C, then put through a **DRYING** process at 40-70 C under partial vacuum to ensure a low residual moisture content (< 3% ) in the final product. The carmine may be **MILLED** in a stainless steel ball mill to suit client specifications on final particle size distribution. Finally, the carmine powder is tightly sealed in the **PACKAGING** line in 10-25 kg moisture-proof polythene containers ready for shipping.

Quality and process control require

- : carminic acid and trace element analysis of the feed material and the carmine product;
- : end-point monitoring of the extraction stage ;
- : pH control throughout ; and
- : colour certification of the product.

No procedures have been identified for the secondary processing or disposal of solid and liquid waste streams.

To achieve these process steps, the following partial list of equipment will be required, scaled of course, in size and capacity to suit the intended production rate of carmine, say, about 10- 40 kg carmine per day ( 24 hrs ). The list below shows the size or capacity of the item envisaged for a batch size of the order of 50 kg dried cochineal that will yield 11-12 kg carmine.

| <u># Units</u> | <u>Unit Description</u>                      | <u>Capacity/Size/Rating</u>            |
|----------------|----------------------------------------------|----------------------------------------|
| 1              | stainless steel extraction tank with stirrer | 2000 litres/ 3 HP stirrer @ 30 rpm     |
| 1              | stainless filter basket                      | 120 litres                             |
| 1              | stainless steel precipitation tank           | 4500 litres/ 3 HP stirrer @ 100 rpm    |
| 5              | stainless steel storage vessels              | 4500 litres, 2 with lid-mounted sieves |
| 1              | stainless steel ball mill                    | 10 kg / hour                           |
| 1              | hammer mill                                  | 15 kg / hour                           |
| 1              | disc centrifuge                              | 50 litres                              |
| 1              | tunnel drier                                 | 1 m dia. x 2.5 m length                |
| 1              | boiler                                       | 40 HP, with water softening            |
| 1              | sieving machine                              | ( 8 - 150 mesh )                       |
| 2              | weigh scales                                 | Up to 150 kg                           |
| 1              | electronic balance                           | Up to 2 kg                             |
| 1              | de-ionised water supply system               | 50 litres / min.                       |
| 1              | packaging machine                            |                                        |

To effect proper quality control of the process and product, a laboratory test facility will be required, containing :-

|             |           |
|-------------|-----------|
| colorimeter | pH meters |
|-------------|-----------|

spectrophotometer  
analytical balance

wet chemistry equipment  
particle size analyser

The market identifies 2 distinct grades of carmine, one for the food industry, with a blueish hue to the red colour; and the second for cosmetic applications, distinguished by its yellow tone. These colour differences are quantitatively defined, and assessed, by the colorimeter. Other product characteristics controlled to suit customer specifications include trace element analysis (e.g., Pb, As ), carminic acid content, and particle size distribution.

### **Overview of the Cochineal / Carmine Industry**

On the supply side of the equation, Peru dominates the production volume and pricing of both the raw material, cochineal, and its processed carmine products. At the user end of the market chain, the US and European food, pharmaceutical, and cosmetics manufacturers look for the same constancy of price and quality in carmine that they were used to with synthetic colorants, and tend to look to Western suppliers, rather than Peru, to guarantee this consistency and repeatability of product in terms of colour and purity. The carmine industry therefore has a primary component extracting carminic acid products from cochineal, and a secondary sector which buys, blends, homogenises and packages carmine products for end user consumption.

Many Western companies only blend and package, while a smaller number bridge the supply line from purchased cochineal to processed and standardised carmine products ready for use in consumer goods. It is believed that, of the South American carmine producers, Peru, and to a lesser extent Chile, do not sell directly to the end user.

As noted above, Peru continues to dominate the industry, harvesting 80% of the world's production of dried cochineal. From that, Peru supplies 82% of the cochineal processed outside of South America, and itself makes 40% of the world's carmine products. Before exploring such statistics in more detail, however, it is useful to record some facts about the industry, starting with the beetle itself. It is estimated that approximately 80% of the annual cochineal harvest is collected from wild plants, and the balance from managed plantations. The latter are increasingly associated with on-site processing plants, e.g., Colca APX in Peru, and Colores de Chile in Chile. The median yield of dried cochineal from plantations is about 500 kg over 3 harvests per hectare per year, although yields may range from 300-1500 kg depending on plant size and the percentage of the plant surface infested. Following harvest, the drying process reduces beetle weight to 1/3 of original. The dried cochineal is graded # 1, 2, or 3 in order of decreasing particulate size, and, it so happens, carminic acid content. Grade #1 is the common export quality, containing 20-22 % carminic acid. The product is sold by the rural farmer / family to a collector, then to a wholesaler, and finally to the exporter. It is not known what fraction of the eventual sale price, e.g., USD 27/kg FOB Lima, is retained by the rural farmer who harvested the cochineal.

The dried cochineal is then processed in a batch system to yield carmine products. The

processing stage is kept highly secret , indeed the only public disclosure is that made by ITINTEC on the details of the IDRC extraction work. Information on the products is more accessible. There are at least 4 identifiable forms of cochineal-based colorant. The most common is the carmine lake, as produced by IDRC's process. This is a complex aluminium / calcium salt of carminic acid, insoluble in water, with different grades containing between 50 and 65 % carminic acid.. It may be converted into a water and acid soluble chelate variant by further chemical processing. The third form of colorant is carminic acid, a red-orange powder produced by treating and spray drying the liquor from the initial alkaline digestion step of cochineal processing. This variant is therefore aluminium and / or calcium free, and is readily soluble in water and common organic solvents. Lastly there appears to be some considerable trade in carmine solutions, i.e., solutions containing specified concentrations ( 3-10 % ) of carminic acid. Note that the 3% solution is sometimes referred to as ' cochineal '. The largest volume product of these four is carmine lake, containing a minimum 52 % carminic acid. This is derived from dried cochineal containing a nominal 20 % carminic acid, so that neglecting wastage, 2.5 kg dried cochineal are required to produce 1 kg of carmine at 50 % carminic acid content; or 3.25 kg cochineal yield 1 kg carmine containing 65 % carminic acid. Allowing for some wastage and less than perfect recovery, one may note that 3 to 4.5 kg cochineal are required to produce 1 kg carmine. Linking this to harvesting cochineal in an integrated plantation, 1 hectare may yield about 100 kg carmine per annum.

Turning now to the industry production statistics, it is regretted that only data for 1996 have been identified in sufficient detail, and shown below in Table 1.

**Table 1. Global Production Survey: Cochineal**

|                     | Dry cochineal<br><u>produced</u> | Cochineal processed<br><u>in country</u> | Cochineal<br><u>exported</u> |
|---------------------|----------------------------------|------------------------------------------|------------------------------|
| Peru                | 410                              | 180                                      | 230                          |
| Chile               | 40                               | 30                                       | 10                           |
| Canaries            | 20                               | 0                                        | 20                           |
| Bolivia             | 10                               | 1                                        | 9                            |
| Central America     | 15                               | 1                                        | 14                           |
| Developed countries | 0                                | 283                                      | 0                            |
| World Totals        | 495                              | 495                                      | 283                          |

Notes:

- Production figures are in metric tonne , based on 1996 data.
- Central American countries include Mexico, Honduras, El Salvador, etc.
- The developed countries importing and processing cochineal to carmine products include Spain, Germany, France, Japan, Italy, USA and the UK.

The uncertainties in the data are more significant with respect to Peru than any of the other producers. The figures of 410 MT harvested and 230 MT exported are probably low as a result of incomplete reporting by producers to government offices. Unofficial sources put the total

cochineal production in Peru at > 500 MT in 1996, 750 MT in 1997, and > 750 MT in 1998, with approximately the same percentages of that harvest processed in Peru.

The steady historical growth of cochineal and carmine production in the period 1985 to 1995 was completely upset in 1995 when the European regulatory aspects of food colouring were changed in favour of the use of natural colorants. Suddenly in 1995, the demand for cochineal exceeded supply by some 100 MT. Prices increased steeply as commodity speculation kicked in. At the higher prices, more insects were harvested than ought to have been, creating a perceived future shortage, and further driving up the price. The market settled down again in 1998, with supply and demand in balance, and prices at normal industry levels ( see below ). The lesson illustrated is perhaps that the market is, by its structure, potentially volatile, and not a secure place to invest in processing technology.

Data were obtained on the extent of global activity in 1996 on cochineal processing, and the results are given below in Table 2. Where specific data on product variants were unobtainable, it was assumed that the product mix made and sold by Peru represented the global distribution of demand for carmine variants, and the activity per variant was calculated accordingly. Thus in the row for Western processors - ' Developed countries ' - the assumption is that the 283 MT cochineal processed was distributed between lake, acid, and solutions in the same proportions as the documented distribution of processed cochineal in Peru. The self consistency of the data in Tables 1 and 2 is reflected in Note 3 in Table 2.

**Table 2. Global Production Survey - Carmine Products (metric tonne)**

|                          | Carmine<br><u>Lake</u> | Carmine<br><u>Acid</u> | Carmine<br><u>Solutions</u> | <u>Totals</u> |
|--------------------------|------------------------|------------------------|-----------------------------|---------------|
| Peru                     | 50.0                   | 8.5                    | 27.0                        | N/A           |
| Chile                    | 8.3                    | 1.4                    | 4.0                         | N/A           |
| Bolivia                  | 0.3                    | 0.05                   | 0.15                        | N/A           |
| Central Americas         | 0.3                    | 0.05                   | 0.15                        | N/A           |
| Developed countries      | 78.6                   | 13.4                   | 42.5                        | N/A           |
| World Totals             | 137.5                  | 23.4                   | 73.8                        | N/A           |
| Carminic acid<br>content | 71.5                   | 23.4                   | 7.4                         | 102.3         |

Notes:

- It was assumed that the Peruvian product mix for 1996 reflects the world demand for carmine products.
- Carminic acid content of lake and solutions are taken as 50% and 10% respectively.
- 102.3 MT of carminic acid from global consumption of 497 MT of dry cochineal reflects recovery of a 20.7% carminic acid content in the cochineal.

To illustrate the inherent consistency of Peruvian data for 1996, a mass balance of carminic acid

was performed and is shown in Table 3. Column B in that Table repeats the published statistics for production, presumably entirely for export as lake, acid or solution, and col. D derives the carminic acid equivalent involved, and hence the cochineal feedstock used. The derived export figure for cochineal is seen to be very close to that separately published.

**Table 3. Cochineal - Carmine Mass Balance - Peru 1996**

| <b>A</b>                           | <b>B</b>           | <b>C</b>              | <b>D</b>                | <b>E</b>            |
|------------------------------------|--------------------|-----------------------|-------------------------|---------------------|
| Processed Product                  | Production tonnage | Carminic acid content | Contained carminic acid | Cochineal processed |
|                                    | MT                 | %                     | MT                      | MT                  |
| Carmine lake                       | 50                 | 50                    | 25                      | 125                 |
| Carminic acid                      | 8.5                | 100                   | 8.5                     | 42                  |
| Solutions                          | 27                 | 10                    | 2.7                     | 13.5                |
| Total cochineal processed in Peru  |                    |                       |                         | 180.5               |
| Total cochineal harvest in Peru    |                    |                       |                         | 410.0               |
| Total cochineal exported from Peru |                    |                       |                         | 229.5               |

Notes:

- Dry cochineal contains 20% carminic acid. Thus col. E = 5xD assuming 100% extraction efficiency.
- Carmine solutions may contain 7.5 to 15% carminic acid. A nominal level of 10% is used here.
- Reported tonnage of #1 grade cochineal exports is 231MT ( c.f. 229.5 above ).

Finally the supply/demand imbalance and the speculation in 1995-1996 are illustrated in the price scenario documented in Table 4, where it is seen that in a very short period of time, the FOB price for cochineal increased by a factor of 3 to 4, and the multiple for carmine was 2 to 3. The modest level of 1998 figures reflects that the Peruvian supply capacity for cochineal, at 750MT per annum, is now in balance with demand. The Peruvian supply side is critical because:

**a)** There is as yet no national sales point for the raw and processed products, allowing foreign buyers to exploit the competition between producers.

**b)** The cochineal and carmine sectors in Peru are by and large separate entities in a business and ownership sense, so that the carmine producers must to a degree compete with the world market to buy cochineal.

**c)** It is quite possible that if the price of cochineal drops below present levels, the local carmine producers will buy and warehouse a high percentage of Peru's cochineal production, creating an artificial scarcity of cochineal for foreign processors, and so leading to a new round of price increases for the raw commodity, and , of course, for the carmine derivative.



**Table 4. Market Price Survey**  
( Price range in USD / kg)

|           | <u>1990</u> | <u>1994</u> | <u>1996</u> | <u>1998</u> |
|-----------|-------------|-------------|-------------|-------------|
| Cochineal | 10 - 15     | 20 - 35     | 60 - 80     | 25 - 30     |
| Carmine   | 100 - 120   | 120 - 150   | 250 - 370   | 130 - 150   |

Notes:-

- 1 kg of carmine lake @ 50% carminic acid requires input of 3 - 4 kg dry cochineal. Thus the market price of carmine must always be > 4 times the input cost of cochineal to properly accommodate processing value added.
- Public data sources were tapped for prices 1990-1996. The figures shown for 1998 were obtained from two separate unofficial sources.

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Beverage Industry, v.89, #5, p24 May 1998
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Food Ingredient News Aug. 19 1998
  19. Carmine additives on FDA ingredient lists  
Food Labelling News Sept. 1998
  20. Can tiny bugs mean gold for Mexico?  
Wall St Journal Oct. 7 1998

## Relevant Web Pages

### Producers

Natural food colours  
Warner Jenkinson Europe

[www.aarkay.com/product](http://www.aarkay.com/product)  
[www.colourcreators.com](http://www.colourcreators.com)

|                           |                                                                                            |
|---------------------------|--------------------------------------------------------------------------------------------|
| Colores de Chile          | <a href="http://www.cochineal.cl">www.cochineal.cl</a>                                     |
| Lansur                    | <a href="http://www.misti.lared.net.pe">www.misti.lared.net.pe</a>                         |
| Propagacion de cochinilla | <a href="http://ekekop.rcp.net.pe">http:// ekekop.rcp.net.pe</a>                           |
| Global Natur              | <a href="http://www.globalnatur.es">www.globalnatur.es</a>                                 |
| Saporiti                  | <a href="http://www.saporiti.com.ar/colorantes">www.saporiti.com.ar/colorantes</a>         |
| Canary cochineal          | <a href="http://www.arrakis.es/~rpdeblas/cochineal">www.arrakis.es/~rpdeblas/cochineal</a> |
| Colca APX - Grupa Inca    | <a href="http://www.colca.com">www.colca.com</a>                                           |

#### Health etc.

|                                         |                                                                                            |
|-----------------------------------------|--------------------------------------------------------------------------------------------|
| Allergy reaction                        | <a href="http://www.med.umich.edu/opm/newspage/dye">www.med.umich.edu/opm/newspage/dye</a> |
| FDA - color additives in food and drugs | <a href="http://www.cfsan.fda.gov">www.cfsan.fda.gov</a>                                   |
| BIBRA toxicity profiles                 | <a href="http://www.bibra.co.uk">www.bibra.co.uk</a>                                       |
| Joint Exec. Comm. Food Additive         | <a href="http://www.inchem.org">www.inchem.org</a>                                         |
| Cosmetic dictionary                     | <a href="http://www.mothenature.com">www.mothenature.com</a>                               |
| U S imports - colorants                 | <a href="http://www.ita.doc.gov">www.ita.doc.gov</a>                                       |
| Peruvian export statistics              | <a href="http://www.minag.gob.pe/MINAG/estadistica">www.minag.gob.pe/MINAG/estadistica</a> |
| Asociacion punto siete - Arequipa       | <a href="http://www.ecouncil.ac.cr/ngoexch">www.ecouncil.ac.cr/ngoexch</a>                 |
| Infobusiness Peru                       | <a href="http://www.icsa.com.pe">www.icsa.com.pe</a>                                       |