

The nature carmine production in Eurasia: from ancient to current time

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Abstract

Until recently in the vast amount of ethnographical literature, in the restoration of the museum exhibits there was confusion about defining the objects that were sources of the red dye-stuff – carmine used in the last 3,000 years for dying cloth, carpets, foodstuffs and in cosmetics. Natural carmine color dyestuff has been made since ancient times from scale insects of three genera: *Porphyrophora* (more than 50 species, family Margarodidae) from roots of several species of herbaceous host plants in Eurasia; *Kermes* (one species, *K. vermilio*, family Kermesidae) from leaves of oak trees in the Mediterranean area; and *Dactylopius* scales (nine species, family Dactylopiidae) from stems of *Opuntia* cacti native only in the Americas. Archeological findings and writings from ancient and medieval times mention the great value of this dyestuff for the robes of the emperor families and clergy because of its brilliant and extremely permanent color. These values resulted in secret production methods, and trade between countries. Archeological information, etymological analyses of these writings and entomological data illuminate the probable origin of the carmine dye industry in Central Eurasia: Persian, Central Eurasian and Altaian areas. The possibility of reviving the carmine dye industry in central Eurasia is analyzed, based on the geographic distribution of indigenous scale insect species. Three methods were analyzed: harvesting the scale insects from natural areas or cultivated fields, production in greenhouses or from tissue culture.

Keywords: insects, carmine, restoration, dye industry.

Introduction

Earlier, the analyses of general information about coccids having dying properties and the etymological analyses of the words associated with these insects by tracing the roots of the words carmine, kermes and cochineal as well as reviving of carmine dye industry in the post soviet countries were given (Jashenko 1993, 1998, 2000; Jashenko and Ambartsumyan, 1999;). Until recently, in the vast amount of ethnographical and historical literature and in the restoration of museum exhibits, confusion existed about the date and origin of exhibits dyed by red carmine dyestuff used during the last 3,000 years for dying cloth, carpets, foodstuffs and in cosmetics (Lucas, 1958; Legget 1944; Dobrinin, 1929 etc.). The confusion also is widespread even in the distinction between the concepts “Kermes” and “Hermes”, the insect sources of the dye, probably because of the consonance in sound between Hermes, the widely known aphid of this genus, and Kermes that belongs to another group of insects – scale insects that are closely related to aphids. The goals of this article are to 1) define the sources of carmine dyestuff from different organisms 2) some review the historical documents on the ancient carmine industry in the Eurasia, 3) propose a hypothesis for the area of origination of the carmine dye industry, and 4) discuss the possibilities for reviving the carmine scale dye industry in Eurasia.

Results

Dyestuff from Different Organisms. All dyestuff can be divided into mineral and organic material, based on its origin (Dobrinin, 1929), and dyes can be made naturally or synthetically. The natural organic dyestuff is divided into dyes of plant, bacterial or animal origin. The excellent review of natural dyes of the world was published in the monograph of D. Cardon (2007) that includes a large part of the animal-based dyes. The animal-based dyestuff of red color is made from scale insects and mollusks.

Purple is an ancient dyestuff, which according to archeological information, appeared on the island of Crete approximately in 1600 B.C. It's produced from the hypobranchial gland secretions of Muricidae mollusks of two species: *Haustellum brandaris* and *Hexaplex trunculus* (older names *Murex brandaris* and *M. trunculus*), inhabiting the Mediterranean Sea.

The other natural animal-based dyestuff of red color (varnish, and dyes with carmine and kermes acids as the base) are mainly obtained from different species of scale insects, that have evolutionarily adapted to feed on the sap of plants. About 8,000 species of scale insects in recent 31 families are known worldwide, most inhabiting the tropical zone. The species of four genera, *Kerria*, *Kermes*, *Dactylopius*, and *Porphyrophora*, are used as raw material for dyeing. Carmine dyestuff is obtained from representatives of two other genera of insects one in the family Margarodidae (genus *Porphyrophora*) and one in the Dactylopiidae (genus *Dactylopius*).

Dactylopius. The term "Mexican cochineal" usually means the species *Dactylopius coccus*, and sometimes also nine other species of industrial importance of this genus (*D. austrinus*, *D. bassi*, *D. ceylonicus*, *D. confertus*, *D. confusus*, *D. opuntiae*, *D. salmianus*, *D. tomentosus*, *D. zimmermanni*) all of which feed on the aboveground parts of Cactaceae, mainly on the genera *Opuntia* and *Nopala*.

Porphyrophora. From this later concept of "cochineal", "Polish cochineal" (*P. polonica*) and "Armenian (Ararat) cochineal" (*P. hamelii*) appeared in the literature. The production of carmine from these two native species that has existed almost 3,000 years has been declining. At present, more than 50 species of scale insects in this genus are known, the majority of which inhabit central Eurasia and Transcaucasia (31 species), as well as the Mediterranean region (14 species), the Far East (3 species), Nepal (1 species) and South Africa (1 species). Carmine dye can be obtained from all representatives of the genus because all produce the dye base carminic acid in their bodies. The majority of the species of *Porphyrophora* are oligophagous and several are polyphagous, that live underground and feed on the underground parts of various perennial herbaceous host plants.

Ancient Historical Documents. The first and most ancient historical document that contains information about the carmine industry and carmine dyestuff is the Bible. In Moses' Pentateuch of the Old Testament, written approximately in the 16th to 15th century B.C, several passages give evidence of carmine scale insects and a developed carmine industry. The settings of the Biblical stories were spread over the Middle East and Northern Africa, as is well known; therefore, the local natural sources, species of the genera *Porphyrophora* and probably *Kermes*,

were used as the dyestuff. Neither Mexican cochineal, discovered by Europeans only at the end of the 15th century A.D., nor the varnish scale insect known in China could have been used in the eastern part of the Mediterranean region. In the Old Testament, the products dyed by carmine scale insects are mentioned 14 times; for example, “*Make the tabernacle with ten curtains of finely twined linen and blue, purple and scarlet yarn, with cherubim worked into them by a skilled craftsman*” (Exodus, 26.1), and “*From the blue, purple and scarlet yarn, they made woven garments...*” (Exodus, 39.1). With these words in the Bible, the yarn industry from fiber dyed by scale insects is mentioned; moreover, the phrase *scarlet yarn* (i.e. dyed by scale insects, or “worms”) is separated in meaning from *purple yarn* (i.e. dyed in purple), because the ancient craftsmen knew the difference in the method of dyeing to obtain hues of different colors. Similar mention about scarlet yarn can be found in other chapters of Exodus (25.4; 39.2) and also in the book of Numbers (19.6).

Armenian (Ararat) carmine scale insect. The use of the Ararat carmine scale insect, *Porphyrophora hamelii*, had great influence on the culture and history of the Armenians and their neighbor countries. The most ancient cuneiform texts about dyestuff obtained from this species of scale insect were left by the Assyrian Tsar, Sargon. Among the rich war booty, he noticed “famous woolen fabrics imported to Assyria in 714 B.C. after destruction of the temple Aik in Mussasyr in the vicinity of Lake Van” (Hechumyan, 1973). Plynii the Elder wrote in his “History of Natural Science” that from Armenia to Rome dye from the “worm” (called Orabits by artists) was exported (Manandyan, 1954). The Armenian Tsar, Trdat the Great, on the coronation of the Roman Emperor was dressed in “tsirani” – ceremonial royal attire dyed by dyestuff obtained from the Ararat carmine scale insect. Dyestuff made from scale insects and used for making prints (impressions) of Patriarch’s and royal seals was also called “tsirani” (Mkrtchyan, Sarkisov, 1985). The first written Armenian sources giving information about Ararat carmine scale insects date back to the 5th century A.D. Armenian historians Lasar Parbetsi and Movses Horenatsi who wrote about “worm” used for dyeing left this information.

Polish carmine scale insect. The Polish carmine scale insect, *Porphyrophora polonica*, also greatly influenced the culture and history of Eastern and European people. Slavic written testimonies about carmine production from the Polish scale insect before the 14th century have not been found. This is related to the generally accepted opinion that in both Russia and Poland from the 12th century all chronicles were mainly devoted to important political events and not to everyday life. The first written document about Polish scale insects was compiled by the Venetian Ermolai Barbus (1493) while translating “De Materia Medica” written by Dioscorid. In footnotes, he mentioned “worms” growing on the roots of the *Saxifraga* plant. These worms can be used for dyeing silk in a wonderful scarlet color. Dyestuff was discovered by the Greeks by chance. They noticed that fecal products of hens eating such worms were colored red. In 1521, the medical doctor Matthias Mechovski from Krakow compiled the “Composition of European Sarmatija” explaining how many dyeing seeds were available in olden times in

Russia, being transported to cities like Genoa or Venice, while in his time they were not harvested anymore and decayed in the fields.

In 19th century Russia, several attempts were made to revive the decaying dyeing industry. During the Turkish expeditions in 1736-1737, adjunct of the Academy of Science G. Junker was accompanying General Feldmarshal Count B. Münnich when he noticed scale insects with which he later experimented on for dyeing fabrics, together with Polotin in 1741 in Moscow. In 1764-67 in Orenburg, Mr. Richkov examined carmine Polish scale insects. Later he published the results in The Memoir of the Economic Society. In 1768, a Senate Order on the necessity of harvesting the adult Polish scale insects not their larva was published. In 1770, a dyer Mr. Tikhonov proposed his way of purification of scale insects from fats. Scale insects should be put first into hot water for 15 minutes, then into hot sand covered by an earthenware plate. Academicians P. Pallas, I. Falk and A. Göldestedt, while traveling all over Russia, wrote about carmine scale insects in their notes. In 1797, the Academy of Science received from the Cabinet of the Emperor “root cochineal” (carmine insects) for examination. These scale insects were collected in the vicinity of Zmeinogorodsk in Siberia. In 1806 and 1807, the Economic Society offered rewards for harvesting scale insects. Mr. Fuhrmann from Kiev was one of the first to receive the reward. He had gathered 2 pood (32 kilograms) of scale insects. In 1814, a gymnasium teacher, Mr. Berlinsky in Kiev, published instructions about how to harvest scale insects. In the same year, G. Kirchhoff, Adjunct of the Academy of Sciences proposed to extract fat from the scale insects using turpentine (Gamel, 1835). Unfortunately all these experiments about reviving the industry of Polish scale insects in Russia did not lead to commercially useful results, so using these species as a source of carmine was forgotten.

Hypothesis for the Origin of the Carmine Dye Industry. Historical and etymological analyses imply that the carmine industry originated in ancient Middle Asia, in the territory of present day Iran, Afghanistan, Uzbekistan and South and East Kazakhstan. The majority of the known carmine scale insects (more than 30 species) inhabit that area. Probably, part of these species were gathered for obtaining dyestuff. While moving from place to place because of military conflicts or other historical events, people discovering scale insects on the new territories started the new industry. The famous Ararat carmine scale insect (*P. hamelii*) likely had been discovered during such a human movement. Due to its high density on its host plants (which means low labor for harvesting) it was the most often used carmine scale insect in the ancient carmine industry. Obviously, later in Europe, the Polish scale insects were discovered, and the Slavs who came from Asia (according to one hypothesis) were among the first collectors. The Arab conquerors in Spain played almost the same role. Having discovered carmine scale insects on the Iberian Peninsula they started to store it for their needs and for sale. As a result, the new name for dyestuff “alkerkes” appeared (Legget, 1944). Probably the carmine industry was brought to Africa as well. Lucas (1958) proves this indirectly in his monograph “Ancient Egyptian materials and industries”. writing: that for coloring Arsinoe fabrics into red crepe, kermes sometimes was used, and that two cases of using a dye called “cochineal” and “Persian cochineal”

were known.

Industrial Possibilities of Carmine Scale Use in Eurasia. Kazakhstan, Armenia, Uzbekistan, Tajikistan, Turkmenistan, Iran, Russia, Belarus, Poland and Ukraine have the most natural resources for development of a carmine industry from *Porphyrophora* (Jashenko, 2009) Rather numerous resources of *Porphyrophora polonica* occur in the European part of Russia, Belarus, Poland and Ukraine, and of *P. villosa* (having a large body size) in Far Eastern Russia. In Armenia, the carmine industry can be renewed on the traditional basis for this natural resource area using *P. hamelii* (Ararat carmine scale insect). Biomass of *P. hamelii* depends mostly on host-plant numbers: average biomass in areas with 3-5 plants per one m² is 4.53 g, and with 10-15 plants per 1 m² is 21.98 g. In general, the biomass of Ararat carmine scale insect in one ha is 150-180 kg; and it is possible to collect 20-40 kg of insects in one generation from one ha without damage to the population. (Mkrtchyan and Sarkisov, 1985). Calculation of the entire distributional area of this species shows a general biomass reserve of 200-250 tons.

In Central Eurasian countries, and especially in Kazakhstan, carmine scale reserves are abundant. The majority of the known species of *Porphyrophora* occur here, which form the basis for genetic selection to improve quality and production. The most promising species for commercial development in Uzbekistan are *P. cynodontis*, *P. sophorae* and *P. epigaea*. Inventories and research is needed on the carmine scale fauna of Tajikistan and Turkmenistan, but in our opinion, two species are most convenient: *P. polonica* for Tajikistan and *P. turkmenica* for Turkmenistan.

The technology for methods of carmine scale cultivation can be developed by three different methods: in the open field, in covered areas in an insectory or in large cages, and in tissue cultures. The first method provides for cultivation of host-plants in the field, distribution of the scale larvae on the plants, hand or mechanical harvesting of adults from the soil or plant roots, and further processing of the half-finished product. Advantages are that this is a rather simple and low cost method of cultivation of the insects. The disadvantages are that a large land area is required and, depending on natural conditions, heavy and expensive hand harvesting may be required. The second method provides for cultivation of the host-plants and scale insects on them in insectary conditions in soil or hydroponics (the most promising method); mechanical or hand harvesting, and further processing of the half-finished product. The positive features are: much smaller rearing areas required (insectary shelves can be built in several levels); a possibility to increase the growing season of the host-plants and numbers of generations of the insects per year; and to increase the number of insects feeding on one host-plant and also on stems and leaves (not only on roots), a constant control on the working insect populations, and a rather easy selection work. The negative peculiarities are the more expensive cost of research in comparison to first direction, and greater expenses for the insectary building. The third method proposes the use of tissue cultures, which produce carmine directly. This method requires high technology and its elaboration is more expensive than other two methods, but the primary product cost will be cheaper. The second and third directions are more promising.

The processing of the half-finished product for obtaining highly cleared carminic acid is planned

in each technology method. The simplest method is as follows: add ether to ground dry scale insects to reduce the wax-like matter, then boil the mixture in water, and precipitate the dye by acetous lead. The received lead lacquer precipitate is decomposed by hydrogen sulphide, the liquid is separated and evaporated, and the residue is dissolved in alcohol. In the Ancient World, each master had his own secrets of obtaining different colored tints of red dye, using salts of different metals. So, the carmine technology can be done only in co-operation with specialists in entomology, genetics, plant physiology and organic chemistry.

In Kazakhstan, 22 species of *Porphyrophora* occur; doubtless, all species can be used in the industry, but some are more convenient than others. According to our analysis of the carmine insect biological features, the following species of *Porphyrophora* are proposed for industrial use in Kazakhstan: *P. sophorae*, *P. gigantea*, *P. polonica*, *P. victoriae*, *P. medicaginis*, and *P. arnebiae*. Females of first three species have large bodies and great fertility. *P. sophorae*, *P. medicaginis* and *P. arnebiae* live on host-plants which are cultivated by some agricultural companies (like alfalfa, Levant wormseed (*Artemisia cina*) and *Glycyrrhiza glabra*) (the latter not abundant or widespread in nature). Establishing carmine production in the open field should be possible, depending on the company infrastructure. That is the most inexpensive method. The females of *P. gigantea* have the largest body size, so it is the most convenient species for research on selection and cultivation in insectary conditions. *P. victoriae* is the only species of the genus, which lives completely on the aboveground parts of the host-plant; that unique feature allows control of the working insect populations. Feeding on aboveground plant parts is a result of adaptation to changed environment conditions, it's a secondary character developed from feeding on the roots (well known for other species of *Porphyrophora*). Therefore, research on genetic selection for species and individuals that live on roots gives positive results very quickly and allows the development of increased insect biomass. At the present time, *P. sophorae* is the most economically promising species for starting carmine production in Kazakhstan.

About half of the known *Porphyrophora* species are distributed in Kazakhstan, so it is important to develop a conservation system for that natural resource. Unfortunately, these insects were not discovered on the territory of zapovedniks (national wilderness reserves). Some conservation is carried out by the botanical reserve "Karatal sand" (*P. gigantea*), Charyn National Park (*P. sophorae*) and a few zoological reserves (special protected territory for the conservation of some vertebrate animal species): Tarbagatay, Lepsy (*P. polonica*), Balkhash (*P. violaceae*) in East Kazakhstan and Andasay (*P. violaceae*, *P. sophorae*) in South Kazakhstan. In the future, 21 zapovedniks will be established in Kazakhstan, *Porphyrophora* lives on seven of the planned protected territories.

The distribution of carmine insects is sporadic or mosaic, and very often, the population lives on a few tens of square meters. Therefore, their conservation is possible if the population of the territory is completely protected; short-term inundation, fire, ploughing the land, and chemical treatments can destroy a population and restoring it can take tens of years. If a population area is large (which rarely occurs), some part of them must be protected on a few separated areas of from 3-5 to few tens or

hundreds of hectares. It is expedient to create such areas not far from national parks, declaring it as a part of the reserve.

Conclusions

Natural dyestuff for carmine red colors have been produced for 3,000 years or more from native scale insects (order Homoptera: superfamily Coccoidea) that develop on native plants in Eurasia. Four genera of red color producing scale insects have been used, including more than 50 species of *Porphyrophora* (family Margarodidae) from Central Asia to Eastern Europe, one species of *Kermes*, *K. vermillo* (family Kermesidae), from the Mediterranean area, and 1 species of *Kerria*, *Kerria lacca* (family Kerridae) from south Asia. Other species *Dactylopius coccus* (family Dactylopiidae), along with its prickly pear cacti (*Opuntia* spp.) host plants, both native only in temperate North and South America, were introduced from Mexico into Spain, along with its host plants, by the Spanish in the 1500's and thence to other areas of the world. This natural carmine dyestuff in Eurasia also was used in ancient medicines, and with possible applications today. Etymological studies of ancient historical documents and the presently known distribution of the scale insects and their host plant species that produce the dyes, is used to track the geography and development of the ancient carmine dye industry from its origin in Persia and its development in Central Asia, the Mediterranean Area, China and Russia. Both the chemical analyses, the etymological studies and present knowledge of the native geographic distribution of the dye producing scale insects, add valuable information and clarification of the ethnogeography of ancient Eurasian cultures, migrations, and trade between them. The possibilities for reviving the natural carmine dye industry of central Eurasia is possible in three methods (in the open field, in covered areas in an insectory or in large cages, and in tissue cultures). Kazakhstan has great biological resources for modern development of carmine industry.

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