Pre-Columbian functional equivalents of vulcanization and their significance for the history of rubber[1]

Jens Soentgen, March 2014

Soentgen@wzu.uni-augsburg.de

Abstract: Rubber is one of the most important materials in the modern world. The substance has a dual history: one part played out in Central and South America, where rubber was already being used in pre-Columbian times. The other part took place in North America and Europe, where rubber in a certain sense was reinvented. This article focuses on the little-known indigenous use of rubber in South America, especially in the Amazon basin, and demonstrates that the indigenous processing of rubber was in no way inferior to western rubber technology. It is shown that the indigenous people possessed a functional equivalent to vulcanization that made their rubber products resistant to wear and tear. Several arguments that aim to belittle the technological competence of the indigenous rubber technicians are discussed and refuted.

Keywords: Rubber, indigenous inventions, vulcanization, indigenous knowledge, history of chemistry, history of technology, Amazonia, post-colonialism

---

[1] This is the initial draft of a paper, that finally has been published in German language: Jens Soentgen: **Die Bedeutung indigenen Wissens für die Geschichte des Kautschuks. (The Role of Indigenous Knowledge in the History of Rubber),** Published in: Technikgeschichte, Bd. 80, Heft 4 2013, page. 295-324. This English version presents some of the main arguments.

1. Introduction

Rubber is possibly the most unusual material to have become known in Europe since the discovery of metals. Although many new materials demonstrate unusual properties, rubber is still unique in many respects. Rubber was first used by the indigenous peoples of South and Central America. It was, as the Jesuit Bernabé Cobo (1582-1657), who spent 61 years in Central and South America, described it: "*bien conocido en todas las Indias*." (Cobo 1964: 268 = Historia del Nuevo Mundo I, Chapter: XXIX), "well-known in all America". Gonzalo Fernandez de Oviedo, who in his youth had made the acquaintance of Christopher Columbus, relates his astonishment at seeing rubber balls made by the indigenous people: "These balls spring incomparably, for when they are thrown on the ground, they hop up again higher and do another hop and still another and still another ..." Oviedo 1992: 145 = Historia General Y Natural de las Indias I, Libro VI, Cap. II). The ball appeared almost alive and loaded with energy. In Europe there was nothing comparable. More than 200 years later rubber has not lost any of its fascination. The French naturalist Pierre Barrere wrote euphorically in 1743 about rings made of rubber: "The rings are even more remarkable. […] A ring; for example, that exactly encompasses the five fingers of the hand if they are pressed together, can be so stretched, that it not only lets an arm through, but even the entire body. It then contracts together again and returns, through its own elasticity, back again into its former state." (Barrere 1743 : 141) Johann Georg Krünitz, enlightener and encyclopedist, described what he called the "spring resin" (Federharz) with these words: "The most noteworthy characteristic of this resin is its extraordinary flexibility and elasticity or spring power; therefore also the designation of spring = resin, *Resina elastica,* is well-deserved. One could take a piece of it and stretch and distort it as much as one wants, still it always takes on its previous form, even if the attempt is repeated many times. And it behaves just the same if one presses it together. […] One can stretch it to such a degree that it becomes completely transparent." (Krünitz 1789: 75f).

Indeed there are many materials we deal with daily that are elastic, but they are at the same time hard, and their elasticity as a rule only works in a certain direction, not through and through. A tree, for example, equalizes the force of the wind elastically and can bend astoundingly without breaking, but a wooden ball made from this tree is hardly elastic. Only rubber has the special characteristic of being simultaneously soft and elastic. Lüdersdorff, the inventor of vulcanization, stated: "[The spring resin is] a thoroughly peculiar substance, that, belonging neither to the resins nor the gums, stands completely alone. Its unusual elasticity, neither through age nor mechanical means to be suppressed, aligns it to a certain extent with living organisms" (Lüdersdorff 1832: 15). The mixture of pleasant softness and astounding elasticity lends the substance a comical gesture; it can stomp and shake like a clown, an impression that Gottfried Semper, who in 1860 dedicated an entire chapter to rubber in the first volume of his much-read work *Der Stil in den technischen und tektonischen Künsten oder Praktische Ästhetik*, captured by describing rubber as the “Affe unter den Nutzmaterien” (“monkey among the materials”) (Semper: 21878, 105-112, here 105). The impression of rubber being alive is namely enhanced by its skin-like impression and its unusual smell.

Rubber influenced industrial society after industrialists learned how to deal with it; great companies were founded around it, monstrous profit gained, monstrous crimes committed for it. Without rubber, the industrial revolution would undoubtedly have taken a different course. Without it, today we would live in a different world in which, at a minimum, the automobile would have played a much smaller role if any. Almost all inventions of the industrial revolution were (and are) dependent on rubber, from the steam engine, which cannot function without rubber seals, trains, which use rubber brakes, all electrical machines and devices that use rubber as an insulator, through to airplanes, cars and bicycles, which are conceivable without rubber tires, but which would have been less widespread. The rubber industrialist Paul W. Litchfield, then President of Goodyear Tire & Rubber, summed this up in 1939 with the following comparison: “Think of our industrial structure as a living thing, the skeleton of which is composed of metal and cement, the arterial system of which carries a life stream of oil, and the flexing muscles and sinews which are of rubber.” (Paul Litchfield talk to the American Chemical Society, Boston Massachusetts, September 13, 1939, cited in Tully 2012: 17).

2. Histories of Rubber and the Heritage of the Indigenous People

“Perhaps no other substance has had as much historical information written about it as has rubber. From the early use of natural rubber in the pre-Columbian era and subsequent discovery, experimentation and development of rubber into an industry, to the synthesis of a substitute in the 20th century, there have been many aspects to the evolution of one of mankind’s most important materials” (Long 2001: 493). These are the opening words of the most comprehensive bibliography of the history of rubber to date and which encompasses 255 titles. The length of this list could easily be doubled. Although much has been written on the history of rubber, a closer investigation of the history of this truly exciting substance shows that the interest in the history of rubber is rather one-sided.

If one looks at the history of rubber outside Europe, one encounters little original information based on a study of primary sources, rather abstract generalizations. The general histories of rubber that I consulted (see list below) never devote more than a few, if any, paragraphs to indigenous rubber products. In nearly all of these histories the invention of vulcanization is credited to Charles Goodyear. However, it was the German chemist F. Lüdersdorff who the first to publish the technique in 1832. Vulcanization is generally depicted as a turning-point in the history of rubber that transformed a crude substance out of the woods into a technical wonder-substance that has played a major role in western technology ever since. Here historians have become victims of Charles Goodyear's interpretation of events. He wrote that his process not only improved the substance, "but [...] amounts, in fact, to the production of a new material." (Goodyear, quoted by Woodruff 1958: 10).

The term 'vulcanization' made history and can even be seen to have created a new history. In this sense, Goodyear's invention of the word is as important as that of the technological process itself. Within a few years the term had eclipsed the technological achievements of the indigenous people, which had been well-known until then, and had created the impression that before Goodyear's invention every rubber product, especially those made by the indigenous people, was doomed to rot or get sticky. Modern histories of rubber (see Literature 2) rarely feature the indigenous people of Amazonia as a technically talented and inventive people, if at all. Only in three rubber histories is their technical intelligence appreciated in somewhat more detail (Forbin 1943, Loadman in Giersch 1995, Serier 1994), whereby even in these cases the indigenous people and their inventions are only allocated one or two pages. In this context, the indigenous people's inventions are not considered in the same way as those of the Europeans and North Americans, who investigated and developed their material further. The indigenous people, the logic goes, somehow, presumably by accident, discovered this very special tree in the jungle that produced a special sap which that they allowed to dry and worked into monstrous solid rubber balls which then played a role in special ritual games. In addition, the people thought up a childlike and poetic name: "tears of the tree". Thus the widespread twin images of a childlike and paradisiacal nakedness and barbaric cruelty in offertory rituals that inform the European consciousness of the Middle and South American indigenous peoples to this day became eternalized (Müller 1995: 19-20). The cognitive and intellectual effort it took to make something practical and useable out of this natural material was done by others later. This picture is one-sided. It creates a distorted impression, above all, through omission. No mention is made of the fact that the South American indigenous peoples, the majority of whom did not survive the encounters with the Europeans, possessed and still possess a significant inventiveness. Not only did they create a functional equivalent of vulcanization, they also discovered highly original processing methods and applications for the material. Without these indigenous inventions rubber would be unknown to us. Today it is difficult to present the complete breadth of indigenous rubber use. The inventiveness, the technical competence and the creativity of the indigenous peoples of tropical South America and especially Amazonia shall be demonstrated in particular by returning to the ethnological sources.

3. The Rubber Technology of the Indigenous People: A Functional Equivalent of Vulcanization

Vulcanization sounds like a dramatic process that uses the power of fire to makes a practical and useful material out of an inadequate and sticky substance from the bush. The basic idea to let crude rubber react with sulfur was first published by Lüdersdorff in 1832 (a fact that is ignored or denied in most anglo-american histories of rubber, see Richardson 1858: 110 or Woodruff 1958: 8) and then patented in the USA by Nathaniel Hayward in 1839. The powerful-sounding name 'vulcanization' was not invented, but popularized by Charles Goodyear, who developed the process further. He initially spoke of 'metallization'. The name 'vulcanization' is important as it influences our perspective on the history of rubber. The term suggests not a gradual, qualitative improvement, but a dramatic process that causes an abrupt change of character. Vulcanization turns a barely useful product of the jungle into a universally applicable material. At least, this is the version we read in most histories of rubber.

In fact untreated rubber (i.e. that has only been dried) has the following problems, as Lüdersdorff very clearly described and those who work with rubber know to this day. If one sets a rubber product in the sunlight, "after a short time the disintegration begins. The spring resin ("*Federharz*" = rubber) will first be attacked at the thinnest places; it takes on the impression of the finger, and the lines of the skin remain permanently visible; if one stretches the same, it soon tears […] This condition of change increases more and more, and soon extends through the entire mass which then transitions into the second stage. It becomes very sticky, ever more so, and brings the mass in a flowing condition[…]. The third and final stage involves the mass slowly and progressively drying out, initially on the surface and the formation of a hard skin that increases in thickness […] now the disintegration is finished. The spring resin is now as brittle and crumbly as it was earlier flexible and elastic." (Lüdersdorff 1832: 34f.). Lüdersdorff discovered that this "sickness" could be treated, if not completely cured, by treating rubber with dissolved or powdered sulfur (Lüdersdorff 1832: 62). This technique was later adapted or discovered anew by the American inventors Hayward and Goodyear.

Furthermore, untreated rubber is very susceptible to microbial attack. Rubber goods could rot, as an American rubber historian writes: "It was during the winter of 1832 that Goodyear passed the New York store of the Roxbury Company. Wearing a ragged coat, and a blacksmith's leather apron for additional warmth, he made his momentous visit to the rubber works, and met Proprietor Chaffee. Chaffee welcomed him, and confided the bad news that his goods were going 'sour'. It was true. Rubberized cloth was literally rotting in warehouses: Chaffee had actually buried $20,000 worth of it to keep it off the market." (Wilson 1943: 44, se also 46).

Many rubber historians draw the conclusion from these facts that the indigenous people's material had significant problems that would have hindered its career in the old world had the European or American inventors not improved the material through vulcanization. Already in one of the first treatments of rubber history we read: „It may be safely stated that no chemical discovery within the last century, has produced such wonderful results as those here alluded to. From being a simple gum, the use of which was limited to the erasure of the school boy's blunder, or the merchant's mistakes, India-rubber, by the process of vulcanization, has become one of our most important articles of commerce." (Richardson 1858: 106). Very similar, also the latest rubber-historian, Tully 2011: 40 states: „When Macintosh and Hancock were setting up, rubber goods still had many unpleasant characteristics. They were smelly and while they maintained pliability if wamed by body heat, they would become hard and brittle at low temperatures. A solution to the problem was discovered across the Atlantic." Similar Wilson 1943: 47, who credites the success of rubber completely to Goodyear: „Thanks to the indefatigable Goodyear, rubber was changed overnight from an interesting curiosity to one of the vital substances of the modern industrial world".

In fact, however, the indigenous people possessed at least functional equivalents of vulcanization; their original products did not have the problems described above. With functional equivalent I do not suggest, that indigenous rubber-processing is in any regard equivalent to modern industrial rubber processing. But I will prove that indigenous rubber processing solved the basic problems, that rubber products had in the 19th century. Indigenous rubber processing, that started with latex produced rubber goods, that were not sticky and not subject to microbial downgrading and that did not become brittle when exposed to the sun. In 1999 Hosler et al. showed that latex harvested from *Castilla elastica* mixed with the juice from *Ipomea alba*, a variety of the morning glory family much-loved as a decorative plant, causes the latex to coagulate and improves the elastic properties of the resulting rubber (see Hosler, Burkett, Tarkaian 1999).

In the following section I would like to show that the Mesoamerican processing technique brought to light by Hosler et al. has an Amazonian sibling which is even more efficient at improving the characteristics of rubber: the smoking of rubber. The smoking of rubber is the indigenous equivalent of vulcanization. It does not produce rubber goods of the same quality as modern rubber goods. But it produced rubber goods, that could compete with the vulcanized products of the 19th century, as I will show. Smoked indigenous rubber products were not only highly elastic but also stable. They did not have the "sicknesses" that motivated the development of vulcanized rubber in Europe and North America. An outstanding witness for this is Henry Wickham, who is best known for his theft of rubber seeds in 1876 that undermined the Brazilian monopoly. Wickham was above all an experienced rubber planter and was well acquainted with the processing techniques. He knew the rubber products made with the new European techniques as well as the quality of the indigenous people's original. His verdict: "That the antiseptic smoke-cure is, and will prove to be, the true method of insuring the production of a rubber retaining the characteristic quality of strength and durability under wear and tear and atmospheric variation, together with the important point of being homogeneous and of even quality throughout, I am convinced. It certainly does not seem to have been remembered that certain of the forest Indian tribes of tropical America, for instance, the Guayangomo and other, have for a long time anterior to the incursion of the Spaniard, been in the habit of making rubber goods for their own use – such as the beautifully made quiver covers for their Warali poison darts, and of a quality for strength and durability excelling any European factory-made. In fact, European factory-made rubber perishes so rapidly in these equatorial forests as to become quite soon useless." (Wickham 1908: 30, see also 57).

That such a dedicated expert documented the superiority of the rubber products produced by the indigenous people over the vulcanized factory-produced European or North American wares means it is worthwhile examining how the indigenous people's processing method created such advantages. First it seems appropriate to look at the chemical differences between the milky sap (latex) that drips out of cuts made in the rubber-producing plant and the elastic rubber that is produced from it. The milky sap contains caoutchouc spherules (approximately 35-40%), surrounded by a stabilizing protein layer, and water (ca. 55-60%) as well as additional substances such as salts and alkaloids. There are several theories for why the plant produces the milky sap; they will not be discussed here. If this sap is left to dry it forms milky-opaque films that already show elastic behavior. However, these films are unstable and lose their elasticity in sunlight and air before becoming sticky and then brittle. They can also quickly become moldy or rot. These bothersome characteristics were later seen in Europe and America as a "sicknesses" of the rubber which could be cured with appropriate treatment.

But how did the indigenous people deal with this problem? Here a procedure comes into play which at first appears unimportant and which is usually not recognized as being connected with a transformation in the substance: the indigenous people smoked the latex. The smoking was their functional equivalent of the treatment with sulfur. The process entailed drying the latex juice over a fire made of young twigs and urucari (nuts of the palm *Attalea excelsa*) or inaja-nuts (nuts of the palm *Attalea maripa*. Other palm nuts also appear to have been used, see Wickham 1908: 31).

A good description dating from 1851 describes the indigenous process used on the river island of Gurupa in the Amazon delta: "A fire is made on the ground of the seeds of the nuts of a palm-tree, of which there are two kinds: one called urucari, the size of a pigeon's egg though longer; and the other inaja, which is smaller. An earthen pot, with the bottom knocked out, is placed, mouth down, over the fire, and a strong pungent smoke from the burning seeds comes up through the aperture in the bottom of the inverted pot. The maker of the rubber now takes his last, if he is making shoes, or his mould, which is fastened to the end of a stick; pours the milk over it with a cup, and passes it slowly several times through the smoke until it is dry. He then pours on the other coats until he has the required thickness; smoking each coating until it is dry. Moulds are made either of clay or wood: if of wood, it is smeared with clay, to prevent the adhesion of the milk. When the rubber has the required thickness, the moulds are either cut out or washed out." (Herndon 1853. The technique used today has hardly changed, see Sioli 2007: 91-93). Of course, the carcinogenic substances contained in the smoke meant that this treatment was very damaging to the health of the worker. However, it fulfilled its material purpose. It transformed the crude rubber into the robust, long-lasting product that Wickham described above.

4. Chemical Explanations for the Effectiveness of the Indigenous People's Procedure

The treatment has at least the following six chemical effects: 1) it leads to a coagulation of the caoutchouc spherules, thus bringing about a separation of phases; 2) it removes the water and other substances. Brushing the latex onto clay causes a separation because the water is sucked up leaving behind a rubber film. The heat and smoke cause the caoutchouc spherules, which stick together easily, to coagulate and then enhance the separation of the phases. 3) The treatment preserves the rubber against microbes; 4) it protects the rubber from attack by oxygen in the air, 5) it protects the rubber from attack by UV light; 6) it causes a chemical transformation in which the polyisoprene chains in the latex become linked leading to an increase in elasticity.

Thus smoking the rubber according to this procedure increases its elasticity, reduces stickiness and makes the rubber resistant to air, microbes and light. How is this possible? Smoke is, from a chemical standpoint, a monstrously complex affair, especially when it stems from an incomplete combustion processes, as it does here. Covering the fire with a pot that is open to the top reduces the inflow of oxygen so much so that the fire only smolders and does not burn brightly. The production of the usual combustion products, water vapor and CO2, is reduced by incomplete combustion. In their place a scarcely identifiable wealth of complex organic compounds is produced, that is still not completely understood. Smoke is difficult to analyze, in part because its chemical composition constantly changes. Smoke is a true cornucopia of organic compounds. A more recent investigation states: "The very numerous compounds that result from the charring of the wood – so-called pyrolysis – present a complete cross-section of organic chemistry." (Toth, Wittkowski 1985: 48). The charring occurs at temperatures of 200 to 600 degrees Celsius (Toth 1983: 79). Smoke is a chemical all-purpose weapon; an omnipotent reagent. It is certain that substances which react with the polyisoprene chains in the latex milk are among its contents. The particular smoke created by charring nuts was analyzed over a hundred years ago (Frank and Gädiger 1910), albeit with inappropriate methods (only the distillate and the remainder of the combustion were examined; the particles in the smoke and the gas phase remained unexamined). Nevertheless, the analysis showed that this seemingly extraordinary smoke was similar to the beech wood smoke used in smoke-curing processes. Thus, analyses of beech wood smoke can be useful in the face of a lack of modern investigations of the special smoke from the nuts. Modern methods have identified 412 organic compounds in curing smoke (Toth, Wittkowski 1985: 50, for a review of more recent investigations see Iinuma et al: 2). The total number of compounds was estimated at 10,000 (Toth 1983:38). Besides soot, the smoke contains in particular formaldehyde and other aldehydes, ketones, formic acid, acetic acid as well as higher acids, methanol and phenols in significant amounts and in many variations (Toth 1982: 32). It also contains nitrogenous gases such as nitrogen oxide (Toth 1982: 51).

The acids in the smoke cause the latex milk to coagulate and have an antimicrobial function. Among the additional compounds in the smoke, the group of phenol compounds whose distillate is collectively designated as creosote (from the Greek: meat saver) are especially important active reagents. These compounds have a strong antimicrobial effect which is why they preserve the rubber. The reduction of the pH and the drying also work against microorganisms. Salicylic acid, a phenolic acid contained in the smoke, is known to be an especially effective preservative (Toth 1983: 49, see also 90). At the same time, because the phenols are antioxidants they protect the rubber against oxygen which makes it crumbly (Toth 1982: 90). They have an additional important function, namely linking the polyisoprene chains together.

I was unable to conduct spectroscopic investigations on non-coagulated and coagulated latex or on rubber articles produced by indigenous people. They would be useful as a supplement to the theoretical investigation, but are not indispensable for the presentation of the evidence. Cross-links between polyisoprene chains are first measurable above a given number (Hosler et al. 1999: 1989). It is however plausible that smoking the rubber removes the protein shells around the rubber spherules, thus enabling coagulation, and that the phenols bond the chains directly to each other. This would mean that smoking not only preserves the rubber, but also facilitates the linking of the polyisoprene chains – without sulfur. Three arguments prove that this is indeed what happens. First, phenol-formaldehyde condensates are also often used in modern rubber chemistry as linking agents. The nitrogenous gases contained in the smoke could be effective in this respect and they are similarly used industrially as linking agents. The acid gas process developed by Charles Goodyear in 1837 is based on the treatment of rubber with nitric acid. Second, smoking also causes linking in foodstuffs, for example in sausages, or in hides, shown by the smoked product becoming leathery (Toth, Wittkowski 1985: 57f). The chemical transformation that the smoking causes in the product is recognizable - *ex effectu*. The rubber is no longer formable, rather elastic. The transformation is stable and enhances the typical rubber characteristics. This is only possible if a three-dimensional linking of the polyisoprene chains has in fact occurred. Astoundingly well-preserved caoutchouc artifacts from the Amazon are still displayed in ethnological museums and still show a certain level of elasticity. The aerosols present in the smoke, especially in the soot, have a very important chemical function. Soot is present in significant amounts in the smoke from sulfur fires. 100 grams of wood can produce 1.85 grams of soot (Toth 1983: 51). Soot particles protect against UV rays and are therefore protect against aging. Soot particles absorb UV rays and transform them into heat. Thus they protect the underlying polymer. Using soot as an additive in rubber is standard practice today. It is mixed in with the rubber in roll presses. This is why rubber tires as a rule are black. The protective function of soot particles was rediscovered by S. C. Mote in 1904 (Schidrowitz 1952: 5).

Indeed, it was not possible to produce a hard rubber (Ebonit), a high-grade linked product from latex, using the indigenous people's techniques. Nevertheless, it was possible to achieve the principal goals of the processing, namely stability and elasticity, using techniques that are easily realized in the jungle. The indigenous rubber technology was thus an optimal technical solution adjusted to the specific production environment and the available means – latex, clay and fire – to manufacture a product that withstood all demands and that was even exported to Europe in the 18th and 19th centuries (Schidrowitz 1952: xiii).

Modern research into additional processing techniques is largely no longer possible since the indigenous cultures of Amazonia, except for a tiny remainder, were exterminated or incorporated into the Mestizo peoples. This is especially true of the Omagua, who were famed for their rubber products. However, additional confirmation of the theories presented here could be obtained by analyzing rubber products produced by the indigenous people using spectroscopic methods (IR, NMR). The investigations sought to identify whether carbon linkages could be found, as postulated.

5. Indigenous Rubber Products

The development of the smoking method is only one side of the indigenous people's inventions with rubber. The other side is the development of objects that made use of the extraordinary properties of the new material, thus bringing to light the technical potential of the material. It was extremely bouncy rubber balls that first made Europeans aware of the astounding properties of rubber. Large and small, solid and hollow **balls** were made (Nordenskiold 1918: 85). Ballgames were not only known to the Maya and Aztecs, but throughout tropical South America, the study of travel reports shows. The most vivid description of these ballgames stems from Theodore Roosevelt who on his Amazon expedition observed games played by the Pareci people in southeast Brazil. He was witness to a head-ball game between two teams arranged similarly to European soccer. The (hollow!) ball had to be played exclusively with the head, and Roosevelt wrote admiringly: "It is hard to decide whether to wonder most at the dexterity and strength with which it is hit or butted with the head, as it comes down through the air, or at the reckless speed and skill with which the players throw themselves headlong on the ground to return the ball if it comes down. Why they do not grind off their noses I cannot imagine: Some of the players hardly ever failed to catch and return the ball if it came in their neighborhood, and with such a vigorous toss of the head that it often flew in a great curve for a really astonishing distance." (Roosevelt 1926: 159, further descriptions were compiled by Nordenskiold 1918: 80-84, of these a very detailed description by Gumilla 1745: 190f deserves special mention. A photo of a Paressi-Kabisi head-ball game is shown in Max Schmidt 1914: 183).

Another indigenous rubber product was **enema bags** used for enema injections. They were manufactured using the “lost form” method, in which the product is formed around a clay core which is then washed out through an opening. Sandy clay was used that could easily be pulverized and taken out again. A hollow bird bone was then attached to the flask that served as a tubule. De la Condamine, among others, reports that the Omagua passed around enema bags produced in this way before feasts in order to give the invited guests relief and to guarantee inner space for the uptake of the food and drink to be consumed (de la Condamine 1745: 79f.). Hallucinogenic substances were also introduced through such enemas (Hovorka and Kronfeld 1908: 237). Many travelers reported on the originality of these injectors which, unlike their contemporary European equivalent, worked without a plunger. Franz Veigl, a Jesuit missionary who was active among the Omagua on the upper Amazon in the middle of the 18th century, writes: “The (Omagua) men make several little hollow ‘gourds’ out of a certain special resin, in Peruvian ‘cauchu’ (Kautschu), with a thin, little tube added at the opening. These little bottles or gourds always remain very flexible, and if one squeezes them together, so that the air must go out completely, but then the little tube is held in something liquid, the gourds thereby sucks itself completely full. If one then squeezes it again with the hand, according to the measure of the pressing force, the drawn in liquid, like a sprayer, thus squirts out very far […]”(Veigl 1785: 86f.). Rubber enema bags have the advantage that they allow self-treatment, while injecting fluid with a plunger is not so easy (Krünitz 1789: 82f.) These enema bags aroused immediate interest and provided the Europeans with the inspiration for additional medicinal applications; for flushing, baby milk bottles etc. (Krünitz 1789: 83).

Strips were made from rubber which could be wrapped around various objects to make them watertight (v. Martius 1867: 440). Furthermore, **shoes** were made, **waterproof textiles** and **flasks** (for example Barrere 1743: 139-141). While there was much experimenting with flasks, the usefulness of waterproof rubber textiles was immediately recognized, and they were at first imported and then produced in great numbers.

Rubber was also cast in moulds to make **toy dolls**. Hollow toy dolls were also produced, as Krünitz reports: “Many other different devices and items made of this resin, often non-ceremonial figures of all sorts of animals, balls etc., are imported via Spain from America to us. The items are usually hollow, except for the balls. Almost all are decorated with leaves or other symbols. If one presses on the material it is still soft and it has little taste.” (Krünitz 1789: 82). Rubber still plays an important role in today’s toy market, but it has frequently been replaced by plastic.

The indigenous people also used **rings** fabricated out of rubber that could be used variously as jewelry or for bundling sticks etc. Rubber bands are available today in every supermarket and stationary store and are now common everyday objects.

They were possibly employed by the indigenous people as penis rings to enhance lust, as at least Cornelius Pauw claims: “Since the swelling of the male member sometimes suffers some problems, and indeed those that a man should last of all have happen, the savages of the province where the rubber [the “elastic resin”] grows, have, at the instigation of their wives, recourse to a unique trick to increase the sensation and ecstasy of love: They bring onto the base of the penis a small ring formed out of that resin […]”.(Pauw 1777 : 54) If this is true, then the indigenous people would have been the first to use rubber in what has nowadays become a very broad range of erotic uses.

Medicinal uses have also been reported. One, namely the use for enemas, has already been mentioned. There are more: **rubber lamellae** were used by the Couna in the Darien province on the border of Columbia as biting blocks that were slid between the teeth of those sick with fever so that they did not grind their teeth during their cramps (Forbin 1943:12). The milky sap also appears to have been used variously internally, as Cobo noted, among other things for the treatment of intestinal bleeding (“*curar camaras de sangre*”, Cobo 1653: 269 = Historia del Nuevo Muendo Cap. LXXIX). Furthermore, rubber was used to start fires and for burning torches that burned brightly thanks to the soot particles but that did not drip (v. Martius 1867: 440, Wavrin 1941:179). The Jivaros also used rubber in the conduct of war by throwing burning rubber onto roofs during attacks (Wavrin 1941: 103).

Rubber coatings were used to seal objects, for example quivers for carrying poisoned darts. Blowpipes were also coated with rubber, probably to improve grip.

The variety of applications developed by the indigenous people, of which certainly only a fraction became known to the Europeans and of these again only a fraction was documented, made the material interesting in the Old World.

6. Discussion of an Argument Belittling the Importance of the Indigenous People’s Inventions

The concentration on *Hevea brasiliensis*, a Euphorbiacae found in abundance in certain areas in the Amazon region, creates the impression that it is primarily this plant that is to thank for rubber. This implies that it was a bio-geographical accident and not a cognitive and technical achievement that rubber was only used in the New World. Since this plant grew in South America, especially in the Amazon, the indigenous people simply had to find it. If this were indeed the case, then the entire argument concerning the technological competence of the indigenous people would be weakened. The use of rubber by the American indigenous people would be a discovery, but not an invention. However, the geographical argument can easily be refuted.

It is little known that there are approximately 2000 latex-producing plants (Hess 2008; 166f). Many of them were present in the Old World. For example, latex is produced by *Euphorbia cyparissias*, the Cypress Spurge; *Sonchus oleraceus*, the cowthistle; and *Lactuca viminea*. the switch lettuce. These plants contain even more caoutchuc by dry weight than *Hevea brasiliensis*, albeit in modest amounts (Diels 1918; 303). There are also caoutchuc-producing trees in the Old World, such as the popular fig tree houseplant *Ficus elastica* which comes from India. Likewise, in China and Africa there are also plants that produce latex in abundance. Indeed, there are claims rubber was produced and used in China before the South American rubber products became known. I was unable to confirm this; it seems that the elastic, colored balls brought from China were not really true rubber (Bourgeouis 1784, Lichtenberg 2007: 34, Rehm 1815: 115f; Lüdersdorf 1832; 14, Zhengyi, Raven, Deyuan 2003: 42). The milky sap of a latex-producing plant was also used in southwest Madagascar (Rochon 1792: 132, apparently from a fig tree). However, it seems the Madagascans used it solely for burning torches. It is difficult to identify the plant Rochon describes as there are several latex-producing plants in Madagascar (see Forbin 1943: 19-21).

But maybe these plants do not produce latex of comparable quality? Historical evidence shows high-quality rubber products were also produced using plants present in the Old World once the idea became known: When rubber supplies to the Soviet Union were cut off by the Japanese in World War II, a certain endemic type of daisy (*Taraxacum kok-saghyz*) was cultivated in order to largely successfully guarantee supplies. After the invasion of the Soviet Union by the Wehrmacht, it was also used by the National Socialists (Giersch, Kubisch 1955: 155-157). Today this species is being researched again with the goal of developing an alternative latex-producing plant. Thus it can be seen that rubber could also have been produced in the Old World. The botanical prerequisites were in any case fulfilled. That this happened not in Asia or Africa, but in South America, underscores anew the technical competence of the indigenous people who first used rubber. The Swedish ethnologist Erland Nordenskiold, cited previously, writes: “It is a matter of fact that in pre-Columbian times the [indigenous people of South America] were acquainted with all the qualities that make rubber so valuable in modern industry. No corresponding discovery had ever been made in the Old World prior to the discovery of America, in spite of the fact that rubber trees of various kinds can be found both in Asia and Africa.” (Nordenskiold 1929: 279).

The significance of this discovery becomes appreciable if we imagine that this indigenous discovery had never been made and that Christopher Columbus had discovered a completely uninhabited continent. Surely the Western world would never known maize, manioc, potatoes or cocoa. We would lack important pharmaceuticals such as quinine, curarine, pilocarpine and cocaine. And we would not know rubber. The entire history of industrialization, and thus even of Europe, would have taken a different course without rubber. At a minimum, the automobile would have not been as massively widespread as it would hardly have been marketable without rubber tires.

7. Hypotheses on the Origin of Indigenous Rubber Technology

The indigenous people's treatment of latex is an intentional process of substance transformation and may be called a chemical process. This is chemistry without a laboratory and without test tubes. It can be carried out in a forest with elementary means: fire, smoke, clay and plant sap. However, these primitive means were used to acheive a substance transformation of enormous importance for the history of rubber and thus the indigenous people's accomplishments deserve more detailed study. However, the instruments historians and philosophers of science use to understand inventions do not work in this case.

How could the indigenous people have developed their processes? How did they get their ideas? Any remarks made on the heuristics of the indigenous people are of very little value because of the extremely limited sources available. We only have second-hand descriptions of the indigenous processes and a collection of the objects themselves. A modern ethnographic account of indigenous rubber processing, as we have for indigenous pottery (Silva 2000), including interviews with the workers, remains a desideratum. We do not know what led the indigenous people to think of smoking their rubber. We do not know how they understood or understand their processes. We do not know what they call the different stages of the process or how they describe their aims.

Thus any effort to understand one of their most important inventions will remain fragile. Nevertheless, it may be useful to consider the practices used.

It can be assumed that the discovery of the elastic properties of dried latex juice, which flows out of cuts in the trees and forms thick masses on the ground or trunk, was a casual observation. The earliest use of this sap could have been, as Nordenskiold assumes, to start fires or for burning torches. Von Martius writes: "The inhabitants of Para supposedly learned the use of elastic rubber from the Campevas. If this milky sap from the trees seeps into the ground it hardens thus into irregular masses often of significant size. It is tapicho (correctly tapichügh, that is, 'from deep in the earth') which served in the preparation of torches" (von Martius 1867: 440f). This use no doubt led to the elastic characteristics of such masses being noticed. But how did the discovery that smoking improves and preserves the elastic properties of the rubber come about? The heuristics of trial and error is much too simple an explanation for a complex procedure such as the smoking of latex. The transfer of practices from one functional group to another, which has been intensively investigated especially by the French anthropologist Andre Leroi-Gourhan, could be relevant here. Leroi-Gourhan's favorite example for this stems from the field of mechanics:

people who use the wheel for transportation soon also use the potter’s wheel to model clay (see Leroi-Gouran 2002: 344-345, passim). Another example is the fermentation under controlled conditions used in the preparation of foodstuffs and the production of dyes and materials (Soentgen, Hilbert 2012).

It could well be that the smoking of hides and foodstuffs to preserve them carried out worldwide was carried over into a new field of application, namely the processing of rubber. Smoking meat, fish or animal hides with green wood conserves them (Belitz 1983). It also stabilizes latex products. Of course the transfer of the concept requires adaptations to be made to the original technique: smoking a fish or a piece of hide is quite different to smoking a liquid. Here again creativity is needed. The procedure described above is indeed effort-intensive, but also ingenious. The solution is to repeatedly brush thin films of latex that are then smoked. This exposes the rubber to intensive contact with the reactive smoke and thus causes the reaction to be as complete as possible.

In addition, the indigenous people invented the technique of the “lost form” as detailed above. The technique can not only be used to manufacture hollow forms but also controls the layer thickness. At the same time, the technique guarantees that the latex is smoked through to a certain extent and that the contact surface between the liquid and the smoke is as large as possible.

8. And Goodyear? The Importance of Vulcanization

The much-cited stickiness of earlier American and European industrial rubber products was caused by the fact that they were usually produced by starting with dried (not smoked) latex. This was made to swell up with a solvent. The paste was brushed onto textiles, for example, and thus products with large surfaces such as raincoats were manufactured. When the products were exposed to UV light from the sun, this caused the rubber to become sticky. Furthermore, products manufactured in this way lacked protection against micro-organisms, something that the original indigenous people’s products had as a result of the substances contained in the smoke.

Thus the problems had with the industrial rubber products of the early 19th century were not due to a mediocre quality of the original indigenous substance, rather they were due to the inadequacy of the early industrial methods of working with the rubber. Vulcanization was then invented.

The vulcanization procedure developed by Lüdersdorff, Hayward, Goodyear and others involves mild heating with sulfur. The sulfur works as a linking agent that bonds the polyisoprene chains with each other. From the beginning of the 20th century soot and other light-protecting chemicals and antioxidants have also been added for protection against aging due to the action of light following a discovery by S. C. Mote in 1904 (Schidrowitz 1952: 5). In this way stability with respect to oxygen and heat is increased. This process was of great importance for the European rubber industry because, when applied in combination with the mastication technique developed previously by Hancock, it enabled the rubbe to be formed and made elastic to the desired degree through vulcanization. The indigenous peoples were not acquainted with this process. The key ingredient, sulfur, is not available directly or indirectly in the Amazon valley. The indigenous people did not need the European process, since they could use fresh latex. This was not an option for the European and American users, as Lüdersdorff wrote in his treatise on rubber: "One had … the plant juice of the *Siphonia elastica* (= *Hevea brasiliensis*) … sent. Naturally this could only happen in tightly-sealed metal containers, or in containers of the spring resin itself. However, this made the affair so much more expensive that, although the juice fulfilled the technical requirements, this method also was abandoned." (Lüdersdorff 1832: 20). Latex becomes moldy as easily as milk because its protein, salt and water content means it is a good culture medium for micro-organisms. Therefore the Europeans had to start out with dried rubber and not latex for both technical and economic reasons. But how could it be reshaped?

Herein lay the real achievement of the European and American inventors. Hancock invented the "masticator" which made rubber pliable. Although it made the rubber formable, it was sticky and lost its elasticity. This could in turn be overcome with the vulcanization process developed by Lüdersdorff, Hayward, Goodyear and others, in an economical and industrially compatible way. A cheap and non-toxic substance that was available everywhere in industrial society was used: clearly a brilliant and simple solution. Thus the importance of vulcanization was not that it made an unusable indigenous product useable, but that it enabled the production of rubber goods from dried rubber. It complemented Hancock's mastication process. Together, mastication and vulcanization are the basis of the rubber industry: mastication makes the dried rubber formable while vulcanization stabilizes the new products and gives them back their elasticity and removes their stickiness. Vulcanization was successful because it functioned well both technically and economically.

The cheap, widely available and potent linking agent was incorporated into European and North American industrial production processes and become part of the developing networks of industrial mass production. Sulfur is more suitable than smoke for industrial mass production methods from a practical and technical perspective since, as a powder, it can be more accurately dosed and is easier to handle. Today the European and American rubber industries still start with fully synthetic or natural rubber. Only a few rubber articles are made directly from latex, for example rubber gloves and condoms.

Vulcanized rubber products do not last forever. Despite the advances in rubber technology, rubber is still a reactive polymer which, especially if exposed to sunlight, over time becomes sticky and then cracks. This is why experienced campers who park their vans in the sun for an extended period do not rely exclusively on the technology of the rubber chemist, but prefer to cover the tires of their cars with wood or cardboard.

9. Is Western Rubber Technology Superior to Indigenous Rubber Technology?

The indigenous rubber technology has been discussed and it has been shown that the indigenous people possessed a functional equivalent to vulcanization. They possessed a technological method to enhance the elasticity and durability of their rubber products. However, should it not be stated that Western rubber technology is superior? The answer to this question is evidently “yes”. It is clear that the indigenous people did not develop synthetic rubber, silicon rubber, tires etc. Although I am not inclined to diminish in any way the collective effort of Western rubber chemists and technicians, it should be pointed out that the quality of a technological solution is always relative to a certain ecological and technological situation. Thus we may compare different industrial processes for producing titanium dioxide (or sulfuric acid) in terms of energy-efficiency etc. Here, the external conditions remain more or less the same, and two processes can be compared and the superiority of one process over another can be stated.

However, if we compare indigenous rubber technology with modern Western technology, the external constraints are so different that it is impossible to define a common measure. If we were to rashly state the superiority of western products, we would be committing the same mistake as those historians of science who judge the theories of the past in the light of modern knowledge instead of understanding them in context. Of course Western rubber goods display a much greater variety and inner perfection. However, their production is also dependent on the whole system of modern industry. They are dependent on steel, on diverse chemical products, on electricity, petroleum supplies etc.

The indigenous technology, on the other hand, is optimized for a technological environment that only provides latex, clay, wood and fire. With these minimal production means the techniques produce products which, at this stage of technological development, can only be judged as perfect. The indigenous technology is ingeniously adapted to the production environment of the forest. In this environment, the indigenous technology cannot be substituted with our western technology. If the products that can be realized with this technology are in some aspects inferior to modern Western rubber products, we have, on the other hand, to be aware of the much higher degree of autonomy of the indigenous process: The indigenous process has very few prerequisites. While modern industry could be paralyzed by a major technological crisis that led to problems with electricity supplies, this would not affect the production of indigenous rubber goods in Amazonia.

Therefore the indigenous techniques and Western rubber technology are incommensurable. We can state that the first gave rise to the creation of the second, but we cannot say that modern rubber technology is in an absolute sense superior to the indigenous techniques. The indigenous technology has its own perfection and deserves more interest from historians and philosophers of the history of science and technology than it has hitherto received.

10. Conclusion: Vulcanization and its Repercussions for Indigenous Caoutchouc Technology

It is well known that the industrial implementation of vulcanization led to the take-off of the European and North American rubber industry and this has been shown above from a new perspective. Finally, it is worth looking at the repercussions this invention has had for the descendants of the original inventors of caoutchouc as a new material. What effect did vulcanization have on the indigenous peoples of South America?

The answer can be seen in the caoutchouc objects. As Krünitz and others witnessed, rubber products produced by indigenous people were still being traded on the European market in the late 18th and early 19th centuries. This trade ceased in the middle of the 19th century. The rubber craft of the indigenous people became expendable. They were degraded from skilled rubber technicians to mere caoutchouc collectors whose job was simply to procure the raw product. However, they were indispensible in this respect because latex-producing trees (the most important being *Hevea brasiliensis*) did not form closed forests: “In the extremely polyspecific jungles of the Amazon, with more than 150 tree species per hectare, the rubber trees only grow at intervals apart from each other and never in groups” (Sioli 2007:91). For this and other reasons, latex tappers, the *seringueiro*, must know their way around the forest. The indigenous people remained indispensable for this task for a long time.

However, it was not their technical skills that were important now, rather only their local expertise, and ultimately the quantity of caoutchouc they delivered. The basic elements of the indigenous people’s caoutchouc technology remained in use, insofar as the latex was still smoked layer by layer over a smoldering fire. However, bottles, rings and dolls were no longer manufactured, rather only shapeless, as large-as-possible spheres that were known at the time as “negro heads”. They were destined for export as a raw material for Western industries. This division of labor remained unchanged by the theft of the *Hevea brasiliensis* seeds by Henry Wickham in 1876 and the later invention and establishment of synthetic caoutchouc, which currently makes up about 2/3 of world production. The volume of natural caoutchouc used varied as a result of these historical events, but ever since then it has only been the material itself, and not manufactured objects that have been in demand.

Thus the indigenous people evolved from competent rubber technicians to “*seringueiros*”: caoutchouc tappers. At the height of the Brazilian rubber boom in the late 19th Century the indigenous people were forced to work in many regions. In Putumayo in northwestern Amazonia the Peruvian Rubber Company established a cruel system of forced labor (see Stansfield 1998).

Today there are various places where caoutchouc products such as bags, bottle coolers, mouse pads and other items are once again being manufactured and sold directly by indigenous communities. However, smoking is no longer used as the process is harmful to health and consumes wood (Amaral, Samonek 2006: 23). In the Brazilian state of Acre the indigenous communities are supplied by an NGO with a liquid that appears to contain a chemical cross-linking agent. Which chemical this is remains a secret (Sabino, Zani 2009: 5). This *tecnica social* - social technology – clearly represents indigenous technology combined with Western elements. The new practice is supported by various foundations, the governments of the Amazonian states of Acre, Rondônia and Pará, as well as the Brazilian government, because this offers a way for indigenous people and other marginalized communities which live in the rainforest to generate income without ruining the forest through, for example, illegal logging. At the market on the edge of the Rio+20 conference in Rio de Janeiro, goods manufactured by the *Encauchados*, as the new indigenous rubber workers call themselves, enjoyed great demand.

After many years of decline of indigenous rubber technology, some already see a new "*ciclo da borracha na Amazônia*" - an impending new rubber boom in the Amazon (Rodrigues 2011). A revival of indigenous caoutchouc technology would certainly be most welcome and the new "*social tecnica*" might well be suitable for providing indigenous caoutchouc technologies with access to the market again.

It is doubtful whether the new methods used in indigenous caoutchouc technology are actually, as claimed, more sustainable and less harmful to health. The chemical cross-linking agent that replaces the smoking process is made available to the indigenous people exclusively by specific distributing agencies, creating new dependencies. It is also likely that it carries a health risk.

The popularity in the West of the amazing substance the indigenous people discovered and developed has brought them a lot of suffering over the last two hundred years. The invention of vulcanization made the indigenous caoutchouc technology expendable. The perfection and versatility of indigenous caoutchouc processing methods were forgotten. Whether the new indigenous caoutchouc products do indeed open a new chapter in the history of caoutchouc or whether they perpetuate the old exploitation by new means remains to be seen.

Literature 1. Sources on indigenous rubber technology

Anglería, Pedro Mártir de: Décadas del Nuevo Mundo. Buenos Aires: Editorial Bajel; 1944.

Krünitz, Johann Georg: Oekonomische Encyklopaedie oder allgemeines System der Staats-, Stadt-, Haus- u. Landwirthschaft, und der Kunst-Geschichte, Bd. 22. 1789. Online unter: **http://www.kruenitz1.uni-trier.de/**. Artikel Harz, Feder-Harz.

Nordenskiöld, Erland: Om Indianernes Anvendelse af Gummi i Sydamerika. In: Geografisk Tidsskrift, Bind 24 (1918), S. 80-86. (Beste Übersicht über die Quellen)

Nordenskiöld, Erland: The American Indian as an Inventor. The Journal of the Royal Anthropological Institute of Great Britain and Ireland, Vol. 59 (Jul.-Dec. 1929), pp. 273-309.

Barrere, Pierre: Nouvelle Relation de la France Equinoxiale, Paris: Piget, Damonneville, Durand, MDCCXLIII, (1743)

Bourgeois, M.: Extrait d’une Lettre de M. Bourgeois, Missionnaire, Péking, le 19. Novembre 1784. In: Mémoires concernant Les Chinois, Tome XI, Paris, Nyon, 1786, S. 577-579.

Oviedo y Valdés, Gonzalo Fernandez de: Historia General Y Natural de las Indias. Publicala La Real Academia de la Historia, Primera Parte, Madrid: Atlas 1992 (1535).

De la Condamine, Charles Marie:Relation abrégé d’un Voyage fait dans l’interieur de L’Amerique Méridionale. Paris:Veuve Pissot, MDCCXLV (1745)

Herndon, Lewis.: Exploration of the Valley of the Amazon, Made under Direction of the Navy Department, Washington: Robert Armstrong, Public Printer 1853.

Hovorka, O. V. Und Kronfeld, A.: Vergleichende Volksmedizin. Erster Band. Stuttgart, Strecker und Schröder 1908.

Lichtenberg, Georg Christoph: Physikvorlesung, nach J. Chr. P. Erxebens Anfangsgründen der Naturlehre. Aus den Erinnerungen von Gottlieb Gamauf. Bearbeitet und mit einer Einleitung versehen von Fritz Krafft. Marix Verlag Wiesbaden 2007. Die Erinnerungen wurden erstmals 1808 – 1812 publiziert. Die Vorlesungen von Lichtenberg wurden in den 1790er Jahren gehalten.

v. Martius, Carl Friedrich Philipp: Beiträge zur Ethnographie und Sprachenkunde Amerika's zumal Brasiliens. Bd. I: Zur Ethnographie. Leipzig: Friedrich Fleischer 1867.

Gumilla, Joseph: El Orinoco Ilustrado y Defendido, Historia Natural, Civil, Y Geographica De este Gran Rio Y de Sus Caudalosas Vertientes. Tomo Primero, Madrid: Manuel Fernandez MDCCXLV (1745)

Cobo, Bernabé: Historia del Nuevo Mundo. Primera Parte. 1653. Nova edicion: Biblioteca de Autores Espanoles, Tomo 91, Madrid 1964. S. 268.

Lüdersdorff, Friedrich: Das Auflösen und Wiederherstellen des Federharzes, genannt: Gummi elasticum; zur Darstellung luft- und wasserdichter Gegenstände. Berlin, Verlag bei J.W. Boite, 1832.

Cornelius de Pauw: Recherches Philosophiques sur Les Américains. Tome Premier. A Berlin 1777.

Piso, Willem und Marcgraf, Georg: Historia Naturalis Brasiliae. Lugdun. Batavorum: Apud Franciscum Hackium; et Amstelodami: Apud Lud. Elzevirium 1648.

Platzmann, Julius: Das Anonyme Wörterbuch Tupi-Deutsch und Deutsch-Tupi. Leipzig, B.G. Teubner 1901. Das Wörterbuch baut auf einem 1795 in Lissabon erschienenen auf.

Rehmsche Buchhandlung: Die Botanik nach ihren neuesten Ansichten dargestellt. Zweyte Abtheylung, Wien, Verlag der Rehmschen Buchhandlung 1815.

Rochon, Alexis-Marie de: Des Abbe Rochon, Mitgliedes der Akademie der Wissenschaften zu Prais und Petersburg u. Reise nach Madagaskar und Ostindien usw. Übersetzt von Georg Forster, Berlin, Bessische Buchhandlung 1792.

Roosevelt, Theodore: Through the Brazilian Wilderness and Papers on Natural History. New York: Charles Scribner's Sons 1926.

Schmidt, Max: Die Paressi-Kabisi. In: Baessler – Archiv, 1914, Jg. 4, S. 167-250.

Sioli, Harald: Gelebtes, geliebtes Amazonien. Forschungsreisen im brasilianischen Regenwald zwischen 1940 und 1962, Hg. Von Gerd Kohlhepp, Pfeil Verlag München 2007.

Veigl, Franz Xavier: Gründliche Nachrichten über die Verfassung der Landschaft von Maynas, in Süd-Amerika, bis zum Jahre 1768, beschrieben von Franz Xavier Veigl, in besagter Provinz vormaligem Missionar der Gesellschaft Jesu. In: Christoph Gottlieb von Murr: Reisen einiger Missionarien der Gesellschaft Jesu in Amerika. Aus ihren eigenen Aufsätzen herausgegeben von Christoph Gottlieb von Murr. Nürnberg, Johann Eberhard Zeh 1785.

Wavrin, Marquis de: Les Jivaros. Réducteurs de Têtes. Récit d'Exploration Publié par Gaston Bunnens. Payot, Paris 1941.

Wickham, Henry: On the Plantation, Cultivation, and Curing of Para Indian Rubber (Hevea Brasiliensis) With an Account of its Introduction from the West to the Eastern Tropics. London: Kegan Paul, Trench, Trübner & CO.

Literature 2: Rubber histories

Forbin, Victor: Le Caoutchouc dans le Monde. Payot, Paris 1943.
GIERSCH, Ulrich/KUBISCH, Ulrich (1995): Gummi. Die Elastische Faszination. Ratingen, Berlin: Dr. Gupta.

Jünger, Wolfgang (1940): Kampf um Kautschuk. Leipzig: Wilhelm Goldmann Verlag. (Später zahlreiche inhaltlich stark veränderte Neuauflagen. Die Aussagen im Text beziehen sich auf die Erstausgabe).

Erbstösser, Udo (2008): Technische Kautschuke. Verborgene Alleskönner. Leverkusen: Lanxess AG.

Le Bras, Jean: Le Caoutchouc. Paris: Presses Universitaires de France, 1961 (1945).

Loadman, John (2005): Tears of the Tree: The Story of Rubber – A Modern Marvel. Oxford: Oxford University Press.

Schidrowitz, P., Dawson, T.R. (Hg.): History of the Rubber Industry. Heffer & Sons, Cambridge 1952.

Serier, Jean-Baptiste (1993): Histoire du Caoutchouc. Paris: Editions Desjonqueres.

Tully, John (2011): The Devil's Milk. A Social History of Rubber. New York.

Woodruff, William: The Rise of The British Rubber Industry During the Nineteenth Century. Liverpool University Press 1958.

Wilson, Charles M.: Trees and Test Tubes. The Story of Rubber. New York: Henry Holt and Company 1943.

Literature 3

Amaral, Assuncao und Samonek, Francisco: Borracha Amazônica: Arranjos produtivos locais, novas possibilidades e políticas públicas. Paper do Núcleo de Altos Estudos Amazônicos No 191 (www2.ufpa.br/naea/), No. 191, Abril de 2006.

Baum, Vicki: Cahuchu. Strom der Tränen. Köln: Kiepenheuer und Wisch 1969. Translation of: The weeping wood von 1943.

Belitz, Larry: Brain Tanning: The Sioux Way. Pine Ridge Indian Reservation, Hot Springs 1983.

Blackley, David: Polymer Latices, Second Edition. Vol. 2: Types of latices. Chapman & Hall; London, Weinheim usw. 1997.

Cronon, William: A Place for Stories: Nature, History and Narrative, In: Journal of American history, Vol. 78,4, S. 1347-1376. Washington DC; 1993.

Diels, Ludwig: Ersatzstoffe aus dem Pflanzenreich. Stuttgart: Schweiterbart'sche Verlagsbuchhandlung 1918.

Friederici, Georg: Lehnwörter exotischer Herkunft in europäischen Sprachen. In: Zeitschrift für französische Sprache und Literatur, Bd. 58, 1938, S. 135-155.

Friederici, Georg: Amerikanisches Wörterbuch und Hilfswörterbuch für den Amerikanisten. Deutsch –

Spanisch – Englisch, 2. Ed., Hamburg, Cram, de Gruyter &Co 1960.

Frank, Fritz, Gnädiger: Untersuchungen über die Urukuri-Früchte. In: Gummi-Zeitung, Berlin, Bd. 24, 1910, S. 1328-1329.

Harth, D.: Geschichtsschreibung. In: Historisches Wörterbuch der Rhetorik, Bd. 3, Hg. von Gert Ueding, Sp. 832-870.

Harborne, J.B.: Ökologische Biochemie. Eine Einführung. Heidelberg, Berlin, Oxford: Spektrum Akademischer Verlag; 1995.

Heß, Dieter: Pflanzenphysiologie, 11. Auflage. Eugen Ulmer Verlag Stuttgart 2008.

Iinuma, Y. et al.: Source characterization of biomass burning particles: The combustion of selected European conifers, African hardwood, savanna grass and German and Indonesian peat. In: Journal of Geophysical Research, Vol. 112, 2007, D08209.

Johnson, W.H.:The Cultivation and Preparation of Para Rubber. Crosby, Lockwood and Son, London 1909 (first 1904).

Kopp, Hermann: Geschichte der Chemie. Bd.1. Braunschweig: Friedrich Vieweg und Sohn; 1843.

Leroi-Gourhan, André: Milieu et technique. Paris: Albin Michel; 2002 (1945 / 1973).

Leroi-Gourhan, André: L'homme et la matière. Paris: Albin Michel; 2004 (1943 / 1971).

Nordenskiöld, Erland: The American Indian as an Inventor. In: The Journal of the Royal Anthropological Institute of Great Britain and Ireland. Vol. 59, 1929, S. 273-309.

Pankau, J.G.: Stichwort Erzählung. In: Gert Ueding: Historisches Wörterbuch der Rhetorik. Bd.2, Sp. 1432-1438. Tübingen: Max Niemeyer Verlag; 1994.

Rätsch, Christian: Enzyklopädie der psychoaktiven Pflanzen. Botanik, Ethnopharmakologie und Anwendungen. Aarau: AT Verlag; 2007.
Sethuraj, M.R. und Mathew, N.M.: Natural Rubber: Biology, Cultivation and Technology. Elsevier,

Amsterdam, London, New York, Tokyo 1992.

Rodrigues, Karine: Couro vegetal abre um novo ciclo da borracha na Amazônia. Portal RTS, online unter http://www.rts.org.br/noticias/destaque-1/couro-vegetal-abre-um-novo-ciclo-da-borracha-na-amazonia (30.11.2012).

Schidrowitz, Philipp: Rubber. Methuen &Co., London 1920 (first 1911).

Fabiola Andrea Silva: As tecnologias e seus significados. Um estudo da Ceramica dos asuriní do Xingu e da cestaria dos Kayapo-Xikrin sob umaPerspectivaetnoarqueologica. Sao Paulo, Julho 2000.

Soentgen, Jens: Paradoxographie. Erscheint in: Constanze Rora (Hg.): Ästhetik des Unscheinbaren. Festschrift für Gundel Mattenklott. Berlin: Universität der Künste 2013.

Sioli, Harald: Gelebtes, geliebtes Amazonien. Forschungsreisen im brasilianischen Regenwald zwischen 1940 – 1962. Herausgegeben von Gerd Kohlhepp. München: Pfeil Verlag 2007.

Soentgen, Jens:Stuff: A Phenomenological Definition. In: Klaus Ruthenberg, Jaap van Brakel: Stuff: The Nature of Chemical Substances. Würzburg, Könighausen und Neumann 2008, S. 71-92.

Toth, Lázlo: Chemie der Räucherung. Wissenschaftliche Arbeitspapiere der Senatskommission zur Prüfung von Lebensmittelzusatz- und –inhaltsstoffen. Weinheim 1983: Verlag Chemie.

Tóth, Lázlo und Wittkowski, Reiner: Das Räuchern – aus der Sicht der Chemie. In: Chemie in unserer Zeit, 19. Jg. 1985, Nr. 2, S. 48-58.

Warburg, Otto: Die Pflanzenwelt. Zweiter Band: Dikothyledonen. Vielfrüchtler (Polycarpicae) bis Kaktusartige Gewächse (Cactales). Bibliographisches Institut, Leipzig 1923 (1916).

World Intellectual Property Organization (WiPo): Intellectual Property and traditional Knowledge. Booklet Number 2. Genf (o.J.).

Zhengyi, Wu; Raven, Peter H.; Hong, Deyuan: Flora of China. Vol. 5: Ulmaceae through Basellaceae. Bijing: Science Press & Missouri Botanical Garden Press 2003.