Frédéric Sacc (1819–1890) Contribution to Plant and Animal Physiology

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Abstract

Frédéric Henri Louis Charles Sacc (1819–1890) was a Swiss chemist to whom we owe a detailed study of the colours of animals, the egg yolk, the development of the baby chicken, pectin, several plant principles, and the impact of sodium chloride on agriculture. Sacc studied in particular the development of feathers, their colouration, and its relation to the composition of the blood. He opposed Gobley's conclusions about the composition of egg yolk. His research on the effect of salt on agriculture led him to conclude that the circulation of sodium on the surface of the globe was as important for life of animals and vegetables as that of CO2 and water.

Key words: Colour of animals, Egg yolk, Fertilised egg, Pectin, Resins, Salt in agriculture.

1 Introduction

Frédéric Henri Louis Charles Sacc (1819–1890) born on June 17, 1819 in Cortaillod (canton of Neuchâtel in Switzerland) was the son of a Prussian physician (Guy-Bergeret 2005). After finishing his basic education, he studied chemistry first at Giessen (Germany) and then at Strasbourg (France). Afterwards, he worked on the development of dyes at a printed cloth factory in Thann (Haut-Rhin, France). Between 1845 and 1848, he served as professor of organic chemistry at the Académie of Neuchâtel (Switzerland) and also established a private laboratory for chemical analysis in Faubourg du Crêt. The European revolutionary wave of 1848 forced him to abandon Neuchâtel and continue his chemical career in Alsace and Spain. In 1866, he returned to Neuchâtel to teach at the new Académie de Neuchâtel, a position he kept until 1875. In that year, he moved to South America to serve in various agricultural, mining, and academic activities in Buenos Aires, Montevideo, and Bolivia. Sacc passed away on February 14, 1890, shortly before taking an academic position at the Universidad de Chile. Sacc was married to Salomé Charlotte Bischoff (1823–1905). Four children were born of this union: Caroline Louise, Anna, Louise, and Frédéric. Sacc served in several public and scientific positions, notable among them being a member of the Société Helvétique des Sciences Naturelles, the Société Industrielle de Mulhouse, founding member and delegate of the Société Impériale d'Acclimatation, counsellor of the Société d'Acclimatation de Nancy, correspondent of the Conseils de Salubrité of Haut-Rhin, Berlin, and Moscow, correspondent of the Société d'Histoire Naturelle de Colmar and of the Comice Agricole de Toulon. He was also appointed Chevalier de l'Ordre de Frédéric, an honour decoration of the kingdom of Württemberg (Guy-Bergeret 2005).

Sacc wrote about 90 papers and books (e.g. 1848c, 1861b, 1871c, 1873b) on the subjects of inorganic, organic, and agricultural chemistry, physiology, vegetable principles, toxicology, etc. In addition to the subjects described above, he studied the preparation of potassium xanthogenate (1844, 1846); of succinic acid (1847b) and of

valeric acid (1846–1847c); the separation of benzoic and cinnamic acid (1846–1847b); the nature of carbon (1844–1446a); the effects of dry distillation for classifying organic substances (1844–1846c); functions of the liver (1844–1846d); selenium, its properties and derivatives (1846-1847a, 1847cd, 1848d); the effects of feeding of chicken only with barley (1848a); the seeds of the white poppy (1849b); the use of gums to thicken colours (1857); the formation of succinic acid (1871a); the properties of drying oils (1871b). He analysed the fungus *Agaricus fœtens* (1873a) and the composition of corn (1883) etc. It may be noted that for all his formulas Sacc assumed the old value of the atomic masses: C = 6, H = 1 and monoatomic, O = 8, N = 14.1, HO = water, etc.

2 The colours in animals

In 1806 Louis Nicolas Vauquelin (1763–1829) reported the results of a work intended to understand the composition of human hair and to find if it had analogues in animal economy (Vauquelin 1806). He heated the hair with water in a Papin machine (a pressure cooker) and found that it decomposed partly or totally only when heated above a certain temperature, as evidenced by the presence of ammonia, carbon dioxide, and fetid empyreumatic oil, and the release of large amount of hydrogen sulphide. Heating black hair to a temperature below decomposition released a highly divided black substance that took a long time to settle. This substance was composed of black oil, thick like bitumen, slightly soluble in alkali and alcohol, and containing iron and sulphur attached to one another. Red hair left a red yellowish residue; where again a large amount of oil and sulphur was present with a little iron. The filtrates were nearly colourless; when carefully evaporated they yielded a viscous, sticky substance that did not gel. From these facts Vauquelin concluded that hair was not a gelatinous substance. Vauquelin also dissolved black and red hairs in water containing four per cent of caustic soda. During the dissolution process ammonium sulphide was released, signalling the beginning of the decomposition of black hairs, and leaving finally a black residue formed of a thick oil, iron, and sulphur. Dissolution of hair in potassium hydroxide yielded a black precipitate with lead acetate because of the presence of hydrogen sulphide in it. Each acid operated in a different manner upon the hair. Sulphuric acid and hydrochloric

acid assumed first a beautiful rosaceous colour and then dissolved the hair. Nitric acid yellowed the hair and dissolved it under mild heat. With black hair the resulting solution presented a floating black oily layer while with red hair it was red. Analysis of the ashes of burnt hair showed the presence of iron, manganese, phosphate, sulphate, and calcium carbonate, traces of sodium chloride, and large amounts of silica. Vauquelin concluded that hair was composed of nine different substances: organic matter that constituted the largest part; a small amount of white oil; iron in an unknown state; traces of manganese oxide, calcium carbonate, calcium phosphate; and large amounts of silica and sulphur. Vauquelin also found that black and red hair differed only in the colour of the oil they contained; in white hair the oil was colourless and contained magnesium phosphate, which was absent in coloured hair. Vauquelin inferred from this that black hair owed its colour to the oil and to the presence of combinations of iron and sulphur. Red and blonde colours were due to the presence of red or yellow oil. White hair was colourless due to the absence of black oil and iron sulphides. In addition, he guessed that in hair, sulphur was united to hydrogen (Vauquelin 1806).

Sacc mentioned that Vauquelin did not separate the two colouring matters from their oils and did not analyse them (Sacc 1843). There were many other examples of living organisms that seemed to owe their colour to a mixture of substances. Blood was red but the purity of this colour had been put in doubt. Two coloured red substances had been extracted from it, one yellow and the other blue, although the existence of the latter had been vividly contested. Urine produced red and blue sediments; the first one attributed to rosacic acid (uric acid) and the second to cyanurin. The latter was probably a modified form of rosacic acid because it was soluble in alcohol and its acid solution was red. Uric acid was abundantly present in the excrements of snakes and birds of prey and many of its chemical derivatives presented a tint reminiscent of the most coloured insects. Bile produced a yellow colour that under the influence of nitric acid turned green, then blue, violet, and red, and finally returned to its initial colour. The sweat of the feet of humans suffering from certain illnesses of the lower abdomen offered a blue colour of unknown nature. Cochineal appeared as red when crystallized, although this coloration was fleeting. Sacc did not believe that the

colour was proper of the insect; it had to be combined with matter from the plant, which produced a purpuric fruit. Finally, the cigarette contained a black aromatic ink, little studied, and almost non destructible because of its high carbon content (Sacc 1843).

Sacc added that none of the above colouring substances had been isolated from feathers. No one had studied their rich coloration because it was assumed to originate from a play of light, as occurred with soap bubbles. Sacc believed that this assumption was erroneous because feathers assumed all possible colours with the same facility as vegetables. Scientists seemed to have neglected the fact that the transparent epidermis of the wattle of the cock of India became red under the influence of a flow of blood and, when cold, it turned from a very pure blue to white. Many examples showed the multiplicity of colours exhibited by feathers. It was impossible to attribute the change in colour to an alteration of the feather tissues, which remained unchanged. Nothing opposed the possibility that the colour change was due to the blood or to one of its principles. If the plumage of a cock-of-the-rock owed its brilliant colours to the thin layers conforming the tissue of its feathers, then it would not disappear under the influence of sunlight. It was true that sparkling feathers owed their perennial nuances to the action of light on the thin layer of mucus that conformed them, but if no coloured substance was present, then their colour would be as unstable as that of the mother of pearl or a soap bubble. The art to imitate these beautiful plays of colour had succeeded only with silk because only silk possessed the brilliant analogy of some feathers. The charming shade of the pigeon throat was produced by the interweaving of blue threads running in one direction with violet threads in the opposite. The actual colour was the product of the simultaneous presence of two different coloured substances in the same organic tissue. Unfortunately, this phenomenon could not always be explained in the same manner; we could not attribute the bright metallic colorations of the feathers of the Magpie to the action of light on the tissue because on any given day they could appear as matte black, without any reflection. Hence, all feathers contained a colouring substance, except those that were white; actually they had to be colourless and owe their colour to the particular disposition of their layers, which themselves were colourless and translucent, as could be verified when inspected one by one. Mamifers presented these brilliant colours

on the bare parts of their skin, which were tinted by the direct action of the blood. This was the reason for the beautiful blue colour of the muzzle of adult Mandrills and the colours of other monkeys. These colours existed only when the animals were alive and disappeared upon death (Sacc 1843).

The skin of mamifers, generally very transparent as that of humans, was able to assume a variety of colours, under hardly understood situations, but certainly caused by the blood. In general, when the skin was transparent, it changed its colour every time the state of the animal changed; red when in anger and blue under violence. Cold, or any obstacle to respiration or circulation, turned it blue and any effusion of the bile turned it yellow. The colour of the skin could also be changed artificially, black for example, with silver nitrate. Sacc went on to describe similar colour changes in reptiles (having nude skin or with scales), insects, molluscs, and crustaceans (Sacc 1843).

Sacc wrote that in order to understand the large variety of colours, it was necessary to search the mechanism by which they were formed. It was clear that normal coloration was produced by foodstuff because it renovated itself. All animals fed on matter composed mostly of carbon, hydrogen, oxygen, and nitrogen. Sacc believed that the colour of the animal was somehow related to the nitrogen content of its foodstuff. This allowed classifying them in three categories: (1) those ingesting food with little nitrogen (e.g. horses, rats, gazelles, gooses, and turkeys); all of them exhibited brilliant colours; (2) those ingesting food with a large amount of nitrogen (e.g. fierce mamifers and prey birds). These exhibited mostly dull colours, and (3) those ingesting any amount of nitrogen (e.g. frugivorous animals, monkeys, gallinaceans, parrots, etc.). These animals exhibited the flashiest hues. Sacc did not refer to fish, insects and molluscs because they had not been studied. Now, the hairs of the first group were formed by an agglomeration of cells and developed under the epidermis that they traversed, and over the surface of which they elevated, more or less. They consisted of long hollow tubes, usually filled with coloured oil. These tubes fell and renewed the same as feathers. Feathers were created the same as hairs, of an agglomeration of epidermal of longer subsistence. They were wrapped in a long flexible tube, opened at only one end. They seemed to develop in a blood medium, apparently renewable because it was

always coloured red. After some time, the blood disappeared and the adult feather broke its envelope and enlarged along its middle part. Fully developed it consisted of three clear parts: stem, beards, and marrow (Sacc gave a detailed description of each of these parts) (Sacc 1843).

Sacc postulated that feathers and hairs had the same physical and chemical properties. Both were solid and flexible, little susceptible to decay, poor conductors of electricity and heat, little attackable by chemical agents (excepting the alkalis that dissolved them easily), they burned without melting and leaving a light and voluminous carbonaceous residue; they tinted without mordant in coloured dissolutions and were very brilliant when untied. The various colorations produced by the animals were due to the faculty they had, to print their nutritive fluid with one or more modifications. Sacc believed that the colouring principles of hair and feathers had the same origin; they differed by the modifications they experienced after they passed through the teguments. The coloration, most probably, came from the blood because this liquid was able to give the skin so many different colours. Blood yielded two coloured matters: one red with green reflections, the other yellow. Since it contained the three primitive colours, it could produce all the colours presented by animals. The colouring matter of blood was complex; it contained iron in a very special state. The blood of all mailers and birds, always kept it colour, independent of the food intake. Studies about the colour of vegetables had shown that most of them, in the pure state, were colourless and expressed their colour only by absorption of oxygen. It seemed that the colouring substance of hairs and feathers exhibited most of the properties of the colouring matter of vegetables; in its pure state it was probably colourless and remained as such until it was oxidized (Sacc 1843).

3 Egg yolk

Theodore Nicolas Gobley (1816–1878) carried extensive research on the composition of the brain, egg yolk, eggs and sperm of Carp, which culminated in the discovery of lecithin (Gobley 1845ab). In 1845, he reported the analysis of egg yolk and the following facts: (1) egg yolk contained more than 50% of its weight in water; (2) the albuminoidal matter (vitelline) was very similar to the white of the egg, although they differed in their composition;

(c) the fatty material of the yolk (egg oil) was composed of a fix fat and an ammoniacal soap (viscous matter); (d) the egg oil was composed of margarine, olein, cholesterol, and a colouring substance, and did not contain sulphur or phosphorus; (e) the yolk cholesterol was identical to the one present in bile; (f) the ammoniacal soap contained oleic, margaric, and glycerophosphoric acids. The combination of these three acids with ammonia was enclosed within a nitrogenous substance different from vitelline; (g) the yolk was neutral or slightly acid, probably due to lactic acid; (h) the colouring matter was formed by two substances, one red, containing iron and similar to the colouring matter of blood, and the other, yellow, probably similar to the one in bile; and (i) the average composition of the egg yolk was 51.486% water, 15.760% vitelline, 21.304% margarine and olein, 0.438% cholesterol, 7.226% oleic and margaric acids, 1.200% glycerophosphoric acid; 0.034% ammonium chloride, 0.277% sodium and potassium chlorides and potassium sulphate; 1.022% calcium and magnesium phosphates, 0.400% meat extract, and 0.853% of ammonia, a nitrogenated substance, colouring matter, traces of lactic acid, iron, etc. (Gobley 1845ab). These papers brought a prompt response from Sacc (1844–1846b). He was surprised that Gobley had reported the presence of an acid in egg yolk, neither looked into the composition of the albumen fraction nor provided any information about the foodstuff ingested by the hens that had laid the eggs. He had neither reported how old the eggs were nor if they were fertilized. Gobley had ended his paper indicating that he intended to study the effect of life on the various constituents of eggs (Sacc 1844–1846b). Sacc reported the results of the experiments he had done with two eggs of bantam hens, laid on consecutive days and cooked the following day. The ether extract contained a fatty material composed of two fats, one substantially more fluid than the other. The oil of the egg was coloured orange yellow; it rapidly absorbed oxygen from the air and became resinified. It smelled like phosphine, indicating that it contained a larger amount of phosphorus, free or combined. Sacc added that he had used in his experiments eggs laid by hens fed only with barley (Sacc, 1844–1846b).

Gobley had mentioned that the egg yolk contained an acid that did not act on litmus or other reactive papers. According to Sacc, on heating egg yolk became acidic when done in the presence of water; hence, the acid mentioned

by Gobley was not a component of egg yolk but a consequence of his analytical procedure. If there were such an acid in the egg yolk, it would have been neutralized by the large amount of alkali contained in the albumin. This was a serious error because it negated the accepted principle that life does not develop in an acidic medium. Sacc added that if Gobley had carried his analyses with eggs of different farms, he would not have obtained the coherent figures mentioned in his papers. These eggs would have come from hens fed with a variety of diets and also of different ages. In addition, Gobley did not analyse the complete egg; during incubation, the chicken that developed in the yellow of the egg absorbed the entire albumin and transformed it into fibrin. Hence it was indispensable to study simultaneously these two principles. Gobley was surprised to have found phosphoglyceric, oleic, and margaric acid. Sacc stated that admitting his finding that the phosphorus was present as a sulphide in the yellow dissolved in the oil, then, upon oxidation, it would yield phosphoric acid and sulphur. This phosphoric acid, in the presence of margarine and olein, would decompose them and combine with their glycerine, generating phosphoglyceric acid and liberating oleic and margaric acid, substances not present in a fresh egg (Sacc 1844–1846b).

4 Development of a chicken egg

Sacc wrote that many experiments had been conducted to discover the influence of food in the maintenance of life. In principle, to answer this question would require carrying experiments during a long period of time on the same individuals receiving a given food and keeping all conditions as equal as possible. This seemed to be an impossible task, which Sacc tried to approximate using a male and female chicken of the variety *Pattue anglaise*, born from the same parents and from the same hatching (Sacc 1847a). The experiments were conducted with both birds enclosed in a cage provided with a double bottom to receive all their droppings. Sacc described in depth all the arrangements done to feed and maintain the birds, as well as the feed composition (barley, limestone, and gravel) and schedule. The initial experiments were devoted to determine the quantity and nature of the barley consumed as well as the composition of their droppings (these were always excreted during the first hours of the night). The difference between these two quantities indicated the part of the food that fed the pulmonary and skin secretions, while the increase in weight expressed the amount of food that had been assimilated, due consideration of any egg laid. The following information was usually collected: weight of the cock, hen, egg (raw and dry), and droppings, weight of each of the three components of the feed (barley, limestone, and gravel), elemental analysis of the barley, (carbon, hydrogen, oxygen, nitrogen, and cinders), and composition of the excrements (organic and inorganic substances, carbon, hydrogen, oxygen, nitrogen, sulphur, cinder) (Sacc 1847a).

The next experiments were related to the determination of the anatomy of the egg, its formation and chemical composition. The information available indicated that the eggshell was almost entirely made of calcium carbonate; for example, William Prout (1785–1850) had reported that the eggshell contained by weight 97% calcium carbonate, 1% calcium phosphate, and 2% organic matter (Prout 1822). The eggshell was permeable to gases and water vapour. The circulation of these principles was fundamental for the development of the baby chicken; eggs covered with a varnish layer never hatched. The internal face of the shell was riddled with small holes to which were attached extensions of the shell membrane (membrana testa), a membrane composed of the reunion of two others, the external, highly rough, and the internal, totally smooth. The albumin (egg white) was located between the shell membrane and the vitellus (egg yolk). The vitelline pellicle (cuticula vitelli) was located below the chalaziferous layer. Above this layer was positioned the cicatricule, inside which the baby chicken was to develop. Sacc continued the subject describing the formation of the egg in the ovary, its separation, and movement in the oviduct. Sacc found that the albumin of the egg was strongly alkaline and the vitellus was neutral. According to Prout, the vitellus contained, by weight, 17% albumin, 29% oil, and 54% water (Prout 1822). Sacc established that the vitellus of the egg of a hen fed with barley, contained, by weight, 19.49% albumin, 27.84% oil, and 52.67% water (Sacc 1847a).

According to Sacc, when placing a well-formed and fertilized egg at a temperature between 32° to 40 °C, life awakened and was followed by a rapid development of the germ. The resulting evolution went through four phases: (1) appearance of the first rudiments of the embryo until formation of the first circulatory system. This

period lasted about two days; the vascular system surrounding the embryo developed and a circular canal appeared, which would later form the vena terminalis; (2) formation of the second circulatory system, lasting two to three days. This was the most important period in it. All the parts of the embryo were clearly formed. The heart and intestines were beginning to form; the allantois had grown to 11 mm and was very rich in sanguineous vessels; (3) from the appearance of the circulation allantois to the birth of the baby chick. During this period, extending from the six to the twenty-first day, all the organs continued their growth, and the embryo size became about that of the egg, (4) birth of the baby chicken. Its composition was now, by weight 12.0646% eggshell and membranes, 23.4133% baby chicken, 7.8102% fatty matter soluble in ether, and 56.7119% water. Certain organic parts of the egg and the solid secretions of the baby chicken remained attached to the eggshell. Comparison with the composition of the fresh egg indicated that during generation of life, the egg lost water and acquired solid matter. During the first week of life, the weight of the baby chicken increased by about 59% and at the end of this period the first feathers made their appearance. Sacc gave a detailed description of the growth, weight increase, and eating habits of the baby chickens during the following weeks, until full maturity (Sacc 1847a).

5 Pectin

According to Sacc, all the matters intended to form a living organism, were mostly aqueous, unstable, and amorphous, as their importance was higher. Nevertheless, some of them, like pectic acid (pectin), the departing point of all vegetable substances, and albumen, offering a fluid proper to all classes of metamorphosis, were hardly understood (Sacc 1848b, 1849a). The sap of all vegetables contained pectin free or associated with sugar cane (glucose); in every place where these two substances found to disappear, we see the emergence of starch, lignin, and bassorin or inulin. The last two established a continuous transition of pectin to starch. The study of the development of the pea showed that the sugar cane and albumen present in the liquid that bathed the cotyledons of the seeds while they were small and green, disappeared as they matured and were replaced by starch and legumin. In Sacc words,

Lignin was present in all vegetables and consti-

tuted their main component. The tree was not destined only to support the body of the vegetables, to feed insects, and to protect and heat the masters of the world; it also maintained the vegetable life when the aridity of the soil did not offer more food... botanists had proved that trees transplanted from a good to a bad soil lost weight and died, the same like and animal.

Physiologists had proved that albumen changed into muscular fibrin and that under certain circumstances fibrin could reproduce the albumen. Chemists had demonstrated the opposite reaction: lignin, under the influence of nitric acid, returned to the state of pectin. The latter transformation was not normal; it took place only when the vegetable did not find enough food in the soil; it never took place in a plant in full force, receiving enough food in relation to its assimilation capacity. Lignin was a complex matter, composed mainly of cellulose built as elongated fibres filled or embedded with foreign substances (lignose), which provided the characteristic properties to the tree. The cellulose was identical in all vegetables but lignose was extremely more variable. All these characteristics led Sacc to study, in particular, the transformation of pectin into lignin (Sacc 1848b, 1849a).

Sacc used the sawdust from fir trees grown near the town of Rochefort, containing by weight 61.9926% lignin and 38.0074% water. Elemental analysis of the dry material indicated that it contained by weight, 47.91% carbon, 6.46% hydrogen, and 45.63% of oxygen corresponding to the formula $C_{21}H_{17}O_{15}$. Incineration of the lignin yielded a white and slightly grey cinder containing. In the next experiment 200 g of dry sawdust were boiled for several hours with 400 g of water, and 2 kg of nitric acid; distillation of the product separated a liquid phase containing 15.3187 g of oxalic acid, corresponding to about three times the same weight of cellulose. The white and opaque residue was washed with water. Treatment with an excess of aqueous ammonia turned it transparent followed by swelling and dissolution in the liquid. Addition of a much-diluted solution of an acid resulted in the precipitation of pectin as a colourless gel, transparent and thick. Elemental analysis by several methods indicated that it contained by weight, 42% carbon, 6% hydrogen, and 52% oxygen corresponding to the formula $C_{14}H_{12}O_{13}$. Sacc summarized his findings as follows: (1) fir wood is composed of pectin insoluble and another substance (probably lignose) that

after being oxidized and hydrated produced pectin soluble; (2) the cinder of a fir tree grown over a Necomian is essentially composed of oxalic acid; (3) treatment of fir wood with nitric acid transforms it partially into pectin; (3) pectin converts into cellulose or another starchy material or into sugar cane and CO2 and water; and (4) the pectin that generates starchy material is the starting point of all vegetable matter (Sacc 1848b, 1849a). The actual composition of the polymers constituting the wall of plant is much more complex that the one described by Sacc (e.g. Senveldran 1985; Costa and Plazanet 2016).

6 First principle from catechu (*Mimosa catechu, Acacia catechu*)

The solid material obtained by evaporation of water extract of the leaves *Mimosa catechu* is usually employed for dyeing clothes and leather tanning. The extract, slightly astringent, imparts beautiful wood nuances, remarkable for their brilliancy, although not particularly solid. Sacc prepared the dye by dissolving the catechu in acetic acid, thickening the solution by addition of gum, followed by addition of ammonia and cupric acetate. Sacc found that addition of an oxidation agent (potassium dichromate) and contact with air, allowed obtaining a constant hue (Sacc 1861a). Catechu was found to be soluble in boiling water and precipitated from the solution by cooling. It was soluble in alkali and precipitated by addition of an acid. It was also soluble in acetic acid and precipitated by addition of water. Addition of lead acetate to the acetic acid solution resulted in the precipitation of lead tartrate. All these results indicated that catechu was a simple vegetable material. Sacc was able to decompose it into its components by boiling for 30 minutes, crushed catechu in water acidulated with sulphuric acid of relative density 1.836. This treatment was enough for total separation into two phases, a brown solid resinous one and a slightly yellow liquid. During the reaction, the system released a strong smell of salicylic acid. The liquid phase was saturated with calcium sulphate and then evaporated to a syrupy state. Addition of absolute alcohol resulted in the precipitation of a mixture of calcium and potassium tartrates. The solid resin was dried at 100 °C; the dry residue was very fragile, insoluble in water, ether, fatty oils, essential oils, diluted acids, saline solutions, and HCl. Nitric acid decomposed completely. It was party soluble in a so-

lution of sodium carbonate and sulphuric acid of relative density 1.836. According to Sacc, the high insolubility, stability, and magnificent brown colour of this material suggested that it was the colouring matter of catechu. He suggested that in order to fix the catechu on cloths, it was necessary to expose it to humid air and add a fuel agent, such a cupric salt. The only effects of the latter were burning the sweet material present in catechu, and free the dye (Sacc 1861a).

7 Effect of sodium chloride in agriculture

Sacc wrote that there were conflicting opinions regarding the effect of salt on soil. For example, Albrecht Daniel Thaer (1752–1828) claimed that salt employed in large amount destroyed all vegetation, but in small amounts it increased the quantity and quality of the fodder (Thaer 1810). George Sinclair (1787–1834) believed that it was an excellent fertilizer as long as it was not used in excess; on the one hand, it stimulated vegetation and increased the production of fodder because it favoured the assimilation of fertilizer, and on the other, it destroyed parasitic plants and insects, and in hard earths, it helped pulverizing it. Thrown on the fertilizer it favoured decomposition retaining all the ammonia as its chloride (Anonymous 1838). According to Sacc, the conflict originated from the fact that almost all the researchers had not considered the action of the soil on the salt (Sacc 1874). None denied the positive action of salt on animals and of sodium carbonate on plants because it facilitated the absorption of humus by vegetables after formation of sodium humate. The conversion of sodium chloride into sodium carbonate was possible only in soils rich in calcium carbonate, subjected to the action of water and followed by dryness. A double decomposition then took place; the resulting sodium carbonate migrated to the soil surface, effloresced, and combined with the manure. The corresponding calcium chloride decayed and descended to the depth of the soil (Sacc 1874). This double decomposition had already been observed and described by Claude-Louis Berthollet (1748–1822) during his inspection of the shores of Lake Natron in Egypt (Berthollet 1800). Berthollet found that the terrain covered by sodium carbonate layers did not contain sodium carbonate but were always impregnated with the salt, and that the terrain ground where the decomposition of sodium chloride took place always contained a consid-

erable amount of calcium carbonate and was always very humid. Berthollet brilliantly deduced that sodium carbonate had been and was still being formed by a double decomposition reaction between the saturated brine and the limestone bed of the lake. The calcium chloride formed from the decomposition of sodium chloride was very deliquescent and thus permeated deep inside the terrain.

Salt was needed by almost of all domestic animals, and the most, by those inhabiting the coldest and most humid countries, because their fodder was more diluted. Pork did not require it because it caused colic and retention of urine and neither by fowl because it caused them catarrh and mortal bronchitis (Sacc 1874). August von Weckherlin (1794–1868) claimed that salt promoted appetite, favoured fattening and secretion of milk and that its necessity increased as the fodder was more aqueous and less nutritive. Different researchers had determined the optimum amount of salt for each 100 kg of animal, with an average of 8 g per day and 100 kg of ruminant. High doses of salt were poisonous for all animals, for example, 1 to 2 kg for a horse and 250 g for a sheep. These numbers indicated the large amounts of salt that the animal deposited in the soil with the manure. Fresh manure contained the salt, but as it fermented and produced ammonium carbonate it decomposed and transformed into ammonium chloride and then into sodium carbonate, which facilitated the transformation of straw into humus. These facts justified the practice of adding salt to manure because it favoured the decomposition of the debris and the absorption of humus by plants. According to Sacc, an obvious consequence was that sodium had to be present in the cinder of all cultivated plants, and in larger amounts when absorbed more easily by manure. He had analysed the urine of ground marmots fed on vegetables originating from a garden heavily fertilized with cow manure and found that is contained by weight 19.44% urea, 74.23% sodium bicarbonate, 5.67% potassium chloride, and 0.66% of magnesium chloride. Analysis of the cinder of the chicory fed to the marmots indicated that it contained by weight 74.79% sodium carbonate, 11.69% calcium phosphate, 1.51% ferric phosphate, 1.13% silica, 0.46% magnesium oxide, 2.19% chlorine, 4.38% sulphuric acid, and 3.85% potassium. These results justified the knowledge that sodium was the alkali of cultivated plants and potassium that of wild plants. They also proved that the circulation of sodium on the surface of the globe was as important for the life of plants and animals as that of CO_2 and water. Sacc also analysed the urine of cows fed mountain hay and found the presence of calcium bicarbonate, but more, the bicarbonates and hippurates of sodium and potassium (Sacc 1874).

Sacc believed that areas short of alkalis could obtain them by evaporating the urine of cattle. This urine contained 5 g/litre of hippuric acid; hence, the economics of the process was more favourable when carrying the recovery of both chemicals (Sacc 1874).

8 Resins

According to Sacc, resins had hardly been investigated. They offered so many points of resemblance that made of interest to examine their chemical reactions to see if this analogy was apparent or real (Sacc 1869). He found that in spite of their similarity, the chemical differences were so marked that suggested a further study of these important industrial substances. Resins were very similar to solid fats but differed in that they did not stain paper, melted below 100 °C; hardly saponified, and did not burn in contact with an ignited body. Sacc restricted his study to the following resins: copal (secreted by the copal tree *Protium copal*), succin (meerschaum, sepiolite, a hydrous magnesium silicate), dammar (obtained from the *Diterocarpaceae* family of trees), amber (obtained from a fossilized tree), rosin (or colophony, obtained from pines and some other plants, mostly conifers), shellac (secreted by the female lac bug), elemi (secreted by the tree *Canarium luzonicum*), sandarac (obtained from the small cypress-like tree *Tetraclinis articulata*), mastic (obtained from the *mastic* tree (*Pistacia lentiscus*), and carnauba wax (a wax of the leaves of the palm *Copernicia prunifera*), all of which were pulverizable. All these resins were subjected to the action of boiling water, alcohol of 86% strength, ether, ordinary acetic acid, a hot solution of NaOH of l.074 specific gravity, carbon disulphide, oil of turpentine, boiled linseed oil, benzene, naphtha ether, sulphuric acid of 1.83 specific gravity, nitric acid of 1.329 specific gravity, and of caustic ammonia. All resins were applied in powdered state with solvent three times their volume, for at least twenty-four hours, at temperatures varying between 15 and 22 °C (Sacc 1869).

These resins presented the following characteristics: (1) Amber, shellac, elemi, sandarac, and mastic became

pasty before melting; the others liquefied at once; (2) carnauba wax melted in boiling water; succin formed a semi-fluid mass, dammar, shellac, elemi, and mastic became sticky, and copal, amber and sandarac remained unchanged; (3) alcohol did not affect dammar and amber; copal became pasty; elemi and carnauba wax dissolved with difficulty; while rosin, shellac, sandarac and mastic dissolved easily; (4) succin swelled in acetic acid, while all the others showed no effect; (5) caustic soda of specific gravity 1.074 dissolved shellac readily, rosin partly; but had no influence on the other resins; (6), amber and shellac were insoluble in carbon disulphide, dammar and resin soluble, copal simply swelled, while elemi, sandarac, mastic and carnauba dissolved with difficulty; (7) turpentine oil had no action upon amber or shellac; it swelled copal; dissolved dammar, rosin, elemi, sandarac, and carnauba wax easily, and mastic very easily; (8) boiling linseed oil had no effect on copal, amber, and carnauba wax; it dissolved shellac, elemi, and sandarac slowly, and dammar, succin, and mastic easily; (9) benzene did not dissolve copal, amber, and shellac; partially dissolved elemi and sandarac, and carnauba wax more easily; while dammar, resin, and mastic dissolved easily; (10) petroleum ether had no effect on copal, amber, and shellac; it was a poor solvent for resin, elemi, sandarac, and carnauba wax and a good one for dammar and mastic; (11) concentrated sulphuric acid (specific gravity 1.83) did not react with carnauba wax; it dissolved all other resins imparting to them a dark brown colour, excepting dammar, which took a brilliant red tint; (12) nitric acid of specific of gravity 1.329, coloured carnauba wax straw yellow; elemi dirty yellow; mastic and sandarac, light brown; and did not effect the others; and (13) ammonia showed no action upon amber, dammar, elemi, and carnauba wax; but caused copal, sandarac, and mastic first to swell, afterward dissolving them; colophony was easily dissolved (Sacc 1869).

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