JUSTUS VON LIEBIG'S TRANSITION FROM CHEMIST TO AGRONOMIST, ADEPT OF THE ECOLOGICAL AGRICULTURE

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TRANZITIA LUI JUSTUS VON LIEBIG DE LA CHIMIST LA AGRONOM, ADEPT AL AGRICULTURII ECOLOGICE

Rezumat. În acest articol este prezentată o informaţie suplimentară menită să elucideze cum Justus Von Liebig se percepea pe sine ca cercetător în raport cu mediul natural pe care-l explora. Îndemnat de dorinţa de a contribui la o nutriţie mai bună pentru oameni, şi-a început activitatea în laborator, afirmându-se ca un chimist talentat. A mers apoi în mediul rural pentru a înţelege în ce măsură elaborările sale din laborator corespund cerinţelor fermierilor practicanţi, în diferite condiţii (pedoclimatice), precum şi ale nutriţiei umane. Cu cât mai mult se aprofunda în agronomie, cu atât mai bine înţelegea că laboratorul trebuie să servească, dar nu să dicteze agriculturii. Reciclarea substanţei organice devenise mai importantă decât orientarea la inputurile din exterior, deoarece prima ameliorează solul-ecosistema, pe când ultimele tind să distrugă solurile şi, în aşa mod, întregul lanţ trofic. Astfel, Liebig (1803–1873), cunoscut din tinereţe (1823) în întreaga lume pentru descoperirile sale strălucite în domeniul agriculturii, a fost unul dintre primii susţinători ai agroecologiei/agriculturii ecologice (organice, biologice). Din păcate, ultima sa carte *Legile naturale ale gospodăririi*" (1863) n-a fost tradusă şi mediatizată pe larg precum prima sa carte *Chimia Organică folosită în Agricultură şi Fiziologie*"(1840).

Cuvinte-cheie: Liebig, fertilitatea solului, îngrăşăminte minerale, gunoi de grajd, materie organică a solului, agroecologie.

Summary. In this paper we present additional information on the ways wherein Justus von Liebig perceived himself as a researcher and the nature around him that he wanted to discover. Spirited by the drive to contribute to a better nutrition for the people, he started as a gifted chemist in the laboratory, but then went on into the countryside to see how his laboratory findings worked out in farmers' practices, in various countryside's (soil-climate) conditions, and in human nutrition. The more he became an agronomist, the more he realised that the laboratory could serve but should not dictate agriculture. Recycling of organic matter became more important than focusing on external inputs, as the first improved soil-ecosystems whereas the latter tended to corrode the soils, and thus the whole food chain. Justus Von Liebig (1803–1873) is world-wide well-known in agriculture for his brilliant findings as a young scientist (1823), wherein he was, among other things, the founder of bio- and agro-chemistry. Unfortunatelly his book T*he Natural Laws of Husbandry* (1863) wasn't widely translated and vociferated similar to his previous book *Organic Chemistry in its Application to Agriculture and Physiology* (1840).

Keywords: Liebig, soil fertility, mineral fertilizers, manure, soil organic matter, agroecology.

Wikipedia (UK) has it like this: „Justus Freiherr von Liebig (12 May 1803 – 18 April 1873) was a German chemist who made major contributions to agricultural and biological chemistry, and was considered the founder of organic chemistry [1]. As a professor at the University of Giessen, he devised the modern laboratory-oriented teaching method, and for such innovations, he is regarded as one of the greatest chemistry teachers of all time. He has been described as the „father of the fertilizer industry" for his emphasis on nitrogen and trace minerals as essential plant nutrients, and his formulation of the Law of the Minimum which described how plant growth relied on the scarcest nutrient resource (limiting factor), rather than the total amount of resources available (Fertiliser manual) [15, p. 46]. He also developed a manufacturing process for beef extracts, and founded a company, Liebig Extract of Meat Company, that later trademarked the Oxo brand beef bouillon cube. He popularized (though he did not invent) the Liebig Condenser [2]".

As for his academic career it states: „Liebig and several associates proposed to create an institute for pharmacy and manufacturing within the university [3]. The Senate, however, uncompromisingly rejected their idea, stating that it was not the university's task to train „apothecaries, soap makers, beer-brewers, dyers and vinegar-distillers. As of 17 December 1825, they ruled that any such institution would have to be a private venture. This decision actually worked to Liebig's advantage. As an independent venture, he could ignore university rules and accept both matriculated and non-matriculated students. Liebig's institute was widely advertised in pharmaceutical journals, and opened in 1826. Its classes in practical chemistry and laboratory procedures for chemical analysis were taught in addition to Liebig's formal courses at the university".

Until today, this is still quite an interesting and rather delicate issue: the benefits and threats of all kind of links between academia and industry.

„From 1825 to 1835, the laboratory was housed in the guardroom of a disused barracks on the edge of town. The main laboratory space was about 38 square meters (410 sq ft) in size and included a small lecture room, a storage closet as well as a main room with ovens and work tables. An open colonnade outside could be used for dangerous reactions. Liebig could work there with eight or nine students at a time. He lived in a cramped apartment on the floor above with his wife and children [3].

Liebig was one of the first chemists to organize a laboratory in its present form, engaging with students in empirical research on a large scale through a combination of research and teaching [4]. His methods of organic analysis enabled him to direct the analytical work of many graduate students. Liebig's students were from many of the German states as well as Britain and the United States, and they helped create an international reputation for their 'Doktorvater' (Dissertation advisor). His laboratory became renowned as a model institution for the teaching of practical chemistry. It was also significant for its emphasis on applying discoveries in fundamental research to the development of specific chemical processes and products.

In 1833, Liebig was able to convince Chancellor Justin von Linde to include the institute within the university. In 1839, he obtained government funds to build a lecture theatre and 2 separate laboratories. The new chemistry laboratory featured innovative glass-fronted fume cupboards and venting chimneys. By 1852, when he left Giessen for Munich, more than 700 students of chemistry and pharmacy had studied with Liebig [3].

In 1832, Justus Liebig and Friedrich Wöhler published an investigation of the oil of bitter almonds. They transformed pure oil into several halogenated compounds, which were further transformed in other reactions [5]. Throughout these transformations, „a single compound" (which they named benzoyl) „preserves its nature and composition unchanged in nearly all its associations with other bodies [3]." Their experiments proved that a group of carbon, hydrogen, and oxygen atoms can behave like an element, take the place of an element, and can be exchanged for elements in chemical compounds. This laid the foundation for the doctrine of compound radicals, which can be seen as an early step in the development of structural chemistry (www.chemheritage.org).

Writing about the analysis of urine, a complex organic product, he made a declaration that reveals both the changes that were occurring in chemistry over a short time and the impact of his own work. At a time when many chemists such as Jöns Jakob Berzelius still insisted on a hard and fast separation between the organic and inorganic, Liebig asserted:

„The production of all organic substances no longer belongs only to living organisms. It must be seen as not only probable, but as certain, that we shall be able to produce them in our laboratories. Sugar, salicin, and morphine will be artificially produced. Of course, we do not yet know how to do this, because we do not yet know the precursors from which these compounds arise. But we shall come to know them [6]".

Young Von Liebig's arguments against any chemical distinction between living (physiological) and dead chemical processes proved a great inspiration to several of his students and others who were interested in the new materialism. Though Liebig distanced himself from the direct political implications of materialism, he tacitly supported the work of Karl Vogt (1817–1895), Jacob Moleschott (1822–1893), and Ludwig Büchner (1824–1899)."

This upcoming materialism is rather interesting as a new paradigm or belief system, which, as we see further down, puzzled Von Liebig more than many in materialism believing people of today know.

„By the 1840s, Liebig was attempting to apply theoretical knowledge from organic chemistry to real-world problems of food availability. His book Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie (Organic Chemistry in its Application to Agriculture and Physiology) (1840) promoted the idea that chemistry could revolutionize agricultural practice, increasing yields and lowering costs. It was widely translated, vociferously critiqued, and highly influential [3].

Liebig's book discussed chemical transformations within living systems, both plant and animal, outlining a theoretical approach to agricultural chemistry. The first part of the book focused on plant nutrition, the second on chemical mechanisms of putrefaction and decay. Liebig's awareness of both synthesis and degradation led him to become an early advocate of conservation, promoting ideas such as the recycling of sewage.

Liebig argued against prevalent theories about role of humus in plant nutrition, which held that decayed plant matter was the primary source of carbon for plant nutrition. Fertilizers were believed to act by breaking down humus, making it easier for plants to absorb. Associated with such ideas was the belief that some sort of „vital force" distinguished reactions involving organic as opposed to inorganic materials [7]."

In a recent paper I elaborated on this discussion and its ultimate effects on agricultural soils world-wide, referring to the FAO's position around The Year of the Soil 2015 [8]. Even the FAO now realizes explicitly that Von Thaer's observations on the humus degradation by chemical fertilisers were right. Now back to Wikipedia's Von Liebig site:

„Early studies of photosynthesis had identified carbon, hydrogen, oxygen, and nitrogen as important, but disagreed over their sources and mechanisms of action. Carbon dioxide was known to be taken in and oxygen released during photosynthesis, but researchers suggested that oxygen was obtained from carbon dioxide, rather than from water. Hydrogen was believed to come primarily from water. Researchers disagreed about whether sources of carbon and nitrogen were atmospheric or soil-based." Théodore de Saussure's experiments, reported in Recherches Chimiques sur la Végétation [9], suggested that carbon was obtained from atmospheric rather than soil-based sources, and that water was a likely source of hydrogen. He also studied the absorption of minerals by plants, and observed that mineral concentrations in plants tended to reflect their presence in the soil in which the plants were grown. However, the implications of De Saussure's results for theories of plant nutrition were neither clearly discussed nor easily understood [7].

Liebig reaffirmed the importance of De Saussures' findings, and used them to critique humus theories, while regretting the limitations of De Saussure's experimental techniques (De Saussure 1803). Using more precise methods of measurement as a basis for estimation, he pointed out contradictions such as the inability of existing soil humus to provide enough carbon to support the plants growing in it. By the late 1830s, researchers like Karl Sprengel were using Liebig's methods of combustion analysis to assess manures, concluding that their value could be attributed to their constituent minerals. Liebig synthesized ideas about the mineral theory of plant nutrition and added his own conviction that inorganic materials could provide nutrients as effectively as organic sources [3].

In his theory of mineral nutrients, Liebig identified the chemical elements of nitrogen (N), phosphorus (P), and potassium (K) as essential to plant growth. He reported that plants acquire Carbon (C) and Hydrogen (H) from the atmosphere and from water (H2O). As well as emphasizing the importance of minerals in the soil, he argued that plants feed on nitrogen compounds derived from the air. This assertion was a source of contention for many years, and turned out to be true for legumes, but not for other plants [3] (figure 1).

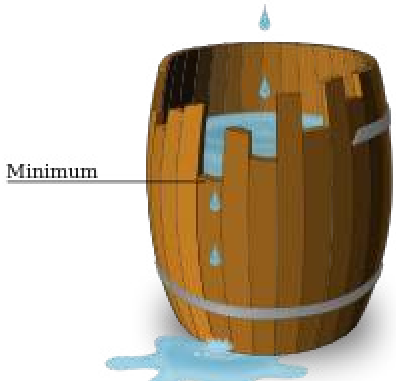

Figure 1. Young Von Liebig's Barrel model.

Liebig also popularized Carl Sprengel's „Theorem of minimum" (known as Law of the Minimum), stating that plant growth is not determined by the total resources available, but by the scarcest available resource. A plant's development is limited by the one essential mineral that is in the relatively shortest supply. This concept of limitation can be visualized as „Liebig's barrel", a metaphorical barrel in which each stave represents a different element. A nutrient stave that is shorter than the others will cause the liquid contained in the barrel to spill out at that level. This is a qualitative version of the principles used for determining the application of fertilizer in modern agriculture.

This is true for mono-factorial experiments which are still dominating in the research agenda. It is enough to change one of the main constituents of the farming systems (crop rotation, for example) and the situation is changing dramatically. Long-term field experiments with and without legumes in the crop rotations at Selectia Research Institute of Field Crops (Balti, Republic of Moldova) [10, pp. 1-13] proved that in crop rotations with perennial legumes the efficiency of supplementary addition of mineral fertilizers to manure isn't reasonable both from agronomic and economic points of view.

Organic Chemistry was not intended as a guide to practical agriculture. Liebig's lack of experience in practical applications, and differences between editions of the book, fueled considerable criticism. Later on, he has recognized that the main obstacle in promoting a good understanding of plant nutrition was complete separation of laboratory science and practice. This statement remains actual even today when agriculture is moved under the preponderant influence of market economy forces without sufficient attention to the environment and social aspects of sustainable development. Nonetheless, Liebig's writings had a profound impact on agriculture, spurring experiment and theoretical debate in Germany, England, and France [3].

One of his most recognized accomplishments is the development of nitrogen-based fertilizer. In the first two editions of his early book (1840, 1842), Liebig reported that there was not sufficient nitrogen in the atmosphere, and argued that nitrogen-based fertilizer was needed to grow the healthiest possible crops. Liebig believed that nitrogen could be supplied in the form of ammonia, and recognized the possibility of substituting chemical fertilizers for natural ones (animal dung, etc.).

Later, however, after years of practical studies in the fields, and finding out about N-fixing organisms in the soil (leguminous crops and others), he came to avow said that in his 'nature's lack-of-Nitrogen perception' he had underestimated the wisdom of the creator. He realized that he had been too early in his conclusions [11], [3].

„He later became convinced that nitrogen was sufficiently supplied by precipitation of ammonia from the atmosphere, and from then on argued vehemently against the use of nitrogen-based fertilizers for many years. This because he had observed how those fertilizers degraded the soil ecosystem. An early commercial attempt to produce his own fertilizers was unsuccessful, due to lack of testing in actual agricultural conditions, and to lack of nitrogen in the mixtures.

When publishing the seventh German edition of Agricultural Chemistry he had moderated some of his views, admitting some mistakes and returned to the position that nitrogen-based fertilizers can be beneficial or sometimes even necessary [3]. Thus he was instrumental in the use of guano for nitrogen. Nitrogen fertilizers are now widely used throughout the world, and their production is a substantial segment of the chemical industry [12].

Now Wolfgang von Haller [12] (1973) published an interesting booklet wherein he had collected various rather unknown quotations von Von Liebig's books, papers and letters to colleagues. The title of this booklet is „Es ist ja dies die die Spitze meines Lebens".

Here we have just selected some parts of these quotations to show how this rarely mentioned side of Von Liebig is remarkably modern, somehow anticipating on the FAO's recent position on agriculture's and human nutrition's future (FAO 2014, 2017… etc.).

So, for example, he says [13]: „I had sinned against the wisdom of the Creator… because I wanted to improve upon his Work and, in my blindness, believed that … He had forgotten a part, which I had to add." He referred to the air's nitrogen that had to be added to the manure, and the other elements in his barrel model. And further on he justifies that in his social network of his early days all chemists meant that plants get their nutrition from nutrients solved in the soil's rainwater. „This was a false idea, and that idea was the source of my foolish behaviour". He goes on stating that chemists usually are no farmers, and therefore can easily see things to simple. „After I had discovered why my manured did not work, I felt myself as endowed with a new life". Stating further on that „… the human spirit is a curious thing: what does not fit in his ideas once they are settled, that does not exist for him".

In between the cited lines he has elaborated on the farm's living soils rust wherein the sun energises the soil-ecosystem (through the plants photosynthesis – feeding from as well as to that soil system) enabling that system to attract and store all elements that plants need to grow, preventing all losses. Recycling of nutrients we would probably say today. He adds that moreover, that soil ecosystem behaves as an amazing cleaner for the water, as it transforms all kinds of organic wastes that originate from animals and plants. Thereby he refers for example to composting and surface manuring.

Further on Haller (1973) [11] cites from the correspondence between Von Liebig and Wöhler [14] (1888), wherein Von Liebig tells how he was invited by the Mayor of London city to design a waste-water-recycling plan, instead of other proposals to ship the town's wastewater to the sea. By collecting the (then mainly) organic material, with loads of proteins (N, P and K), Von Liebig wanted to recycle the cesspools nutrients to the farms, to be added to the straw-rich manures used to feed the soils. Excited he states that „This is the summit of my life". It should be noted that he had learned from China's and Japan's recycling traditions.

In chapter 3 of his last book „The Natural Laws of Husbandry" (1863) which was edited by John Blyth, prof. of chemistry in Queen's College in London, he wrote about the importance of crop rotations and manuring in restoration of soil fertility. So, for example, on clover fatigue soils none of the ordinary manure can help, whether artificial or natural.

In his book on agro-chemistry [14] he stresses the importance to include sawdust from forestry in the manure composting, stating „… I have completely revised my earlier perceptions on plant nutrition and humus building". Now he deems it obvious that the organic degradation of the sawdust makes carbonic acid free to release minerals from the soil, so as to provide more minerals for the crop's nutrition. Today he would presumably add that the carbon brings energy to the soil's ecosystem.

He criticized Lawes and Gilbert from the Rothamsted Experimental Station in UK for their attempts to find different manures that might serve to restore the original productive power of the fields but, according to him, such manure doesn't exist. Today we realize that this was the impact of ploughing virgin soils. The management practices used in agriculture can't compensate the initial losses of soil organic matter from the soils. Only crop rotations with a higher diversity of crops with natural manure can restore soil fertility, according his opinion. This opinion is quite different than his previous one, when he was overestimating the importance of mineral fertilizers in returning the nutrients taken up by crops from the field.

By the way Liebig was mentioning one of the most important methodological aspects for soil tillage which, however, were not taken in consideration by his students and followers. He wrote that mechanical operations (ploughing) do not add nutrients to the soil, but act beneficially by preparing the existing nutriments for the support of future crops. Now we have realised the negative impact of soil tillage and especially of moldboard plough on soil fertility. Faulkner (1943), in his book „Plouman's Folly" [16], wrote that ploughing did so much damage for the humanity which all the wars together didn't. Nowadays conservation agriculture including No-till are becoming common practices [17].

In chapter 5 of his book „The Natural Laws of Husbandry" Liebig (1863) [18] wrote that „the only means to determine the amount of available nutrients are not chemical analyses, but crops themselves". Now we can say that although chemical analyses are important they can't tell the story about the soil health, the life in the soil. The long-lasting civilizations of China and Japan have been determined by their ability to restore (preserve) the conditions of life for their nations.

Liebig was considering that yields are not determined only by the content of nitrogen in the soil. More than this, there doesn't exist a strong correlation between total amounts of nitrogen and yields. Data obtained in the long-term field experiments in different parts of the world, including at Selectia Research Institute of Field Crops in the Republic of Moldova, are proving this statement [19, pp. 175-200; 20, pp. 131-158].

As for human nutrition, he was very concerned about the shift from whole meal to pure-white meal that he regarded decadent and very unhealthy. He had found that pure Wheat and Rye grains contain much less nutritional minerals as compared to meat, and the refined meal much less. He mentions comparative contents of 21 : 13 : 9 for whole meal : meat : refined (white) meal. Thereby he refers to Magendie (1825) [21] who, in an experiment, fed dogs (only) with whole grains or (only) refined flower, and found that the latter died. Von Liebig concludes that many millions of people in all the German States could be sufficiently nourished when they could be convinced of the benefits of eating the black (wholegrain) bread.

Haller (1973) [11] ends his book mentioning Von Liebig's appeal to medical doctors to remind how Hippocrates taught his students to include knowledge of nutrition in their education and practice. This because he had noticed that Inhabitants of jails, slums, barracks and soup-kitchens were quite badly nourished, whereas he meant they deserved an economic but well-balanced food to be healthy and happy in their hard-physical work's life. Dietary expertise in physicians would prevent a wide range of diseases, he foresaw. This because he saw man as an intrinsic part of nature, and thus, according to him, nature's health would go along with humans'.

Reflecting on Von Liebig's remarkable scientific development we can see a brilliant adolescent laboratory chemist, who in the course of his career, more and more went out in the fields where his research findings were applied. There, in a 'Von Humbold'ian (1769–1859) open minded way, full of respect for nature's intrinsic wisdom, he asked himself why his findings did not work out the way he had presumed in his laboratory. He evaluated his hypotheses in some kind of 'dialogue with nature' instead of forcing them on nature, as his subordinate, in order to make her obey his ideas. However, most of his clever and assertive chemical colleagues and students joined his and their early adopted ideas on chemistry leading agriculture, and the linear, pure materialist's rationality. He wrote: „In human society ignorance is undoubtedly the fundamental and therefore the very greatest evil. There is no profession which for its successful practice requires a larger extent of knowledge than agriculture, and none in which the actual ignorance is greater".

The neglect of Von Liebig's self-revision, his transition to thinking the organic, circular or even spiral way is obvious: its absence in agronomy students' textbooks, and research, and so for example also in Wikipedia, is, looking back on his personal development, most striking.

Only around and after the FAO's Year of the Soil (2015), his ideas reappear in today's language in FAO's agricultural and nutritional recommendations [22], [23].

The long-range practice and research of organic, biodynamic, permaculture, agro-eco and similar movements, which were inspired by Von Liebig's later insights and other nature-friendly, 'non-violent' approaches, though largely denied by official agriculture, may well have contributed to the recent FAO's transition. The world-wide application of the FAO's new policy is still hampered by vested interests, and a deep-felt resistance to change-for-the-better. Next generations will have to deal with today's actions.

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