Luiz Alberto Colnago, a prominent researcher in the Analytical Chemistry of Agricultural Products, gave an interview to BrJAC

Luiz Alberto Colnago

Senior Researcher

Embrapa Instrumentação, São Carlos, SP, Brazil

luiz.colnago@embrapa.br

Born in Itarana (Espírito Santo, Brazil), Luiz Alberto Colnago graduated in Pharmacy at the Faculty of Pharmacy and Biochemistry of Espírito Santo (FAFABES) in 1976. He obtained his Master's and PhD degrees in Chemistry, both from the "Instituto Militar de Engenharia" of Rio de Janeiro (RJ, Brazil), in 1979 and 1983, respectively. He developed postdoctoral works in Biomolecular Magnetic Resonance at the University of Pennsylvania, Philadelphia, USA, in two periods: 1983 to 1985 and 1991 to 1992. Since 1986 he has been a researcher at the Brazilian Agricultural Research Corporation (Embrapa), and since 1993 a guest advisor at the Institute of Chemistry and the Institute of Physics, both at the University of São Paulo (USP) in São Carlos, SP, Brazil.

Dr. Colnago is a specialist in *in vivo* or *in vitro* Nuclear Magnetic Resonance (NMR) applied to biological systems and in the development of NMR instrumentation for analysis of chemicals, food, fuels and other products. His researches also include the development and application of other physical methods for the analysis of biological systems of agricultural interest.

His contribution to science was recognized through awards such as: "Highlight in NMR" (2014) by the Association of Magnetic Resonance Users (AUREMN); the "Postgraduate Award", by the Institute of Chemistry of the University of São Paulo in São Carlos (IQSC/USP), for a publication that presented the biggest impact factor in 2012 in the area of Analytical and Inorganic Chemistry; the "Order of Merit Commendation Domingos Martins", by the Legislative Assembly of the State of Espírito Santo, Brazil (2010); and prizes from the Embrapa Awards System (2001 and 1999).

Dr. Colnago and his team are proposing the use of low field NMR using permanent magnets to investigate adulterations in fresh and processed foods, biofuels and biomaterials, and to monitor electrochemical reactions *in situ*, among other applications. In addition to the reduced cost of analysis, which can be tens of times lower than the costs of superconducting NMR equipment, low field NMR equipment allows fast and non-invasive analysis of *natura* foods such as fruits, meats and seeds, as well as in the determination of the quality of industrialized foods such as olive oils, mayonnaise, sauces and jellies, without violation of the packaging

Variety of products that can be analyzed by low field NMR

seal, i.e., directly in the commercial packaging. The researcher's dream is that one day these NMR devices can be in supermarkets so that consumers can assess the quality of the products they are buying, just as they do today with balances to check the weight.

The researcher also participated in a project funded by the Bill and Melinda Gates Foundation, which aimed to help reduce hunger in Africa by improving the transportation and conservation of food produced in the sub-Saharan region. The project had a team of experts in agriculture, basic sciences and engineering to propose innovative solutions for the production chains of milk, maize and cassava, which are the main foodstuffs for people in sub-Saharan Africa.

How did your career begin? What were your motivations?

My interest in science and technology began in my childhood. I spent a good part of my childhood in the garages of my uncle Florival, and a neighbor, Aristeu. In these workshops, they repaired virtually all types of devices – electrical and mechanical – such as watches, radios and electric and combustion engines, among other machines and equipment. During high school I was interested in the study of medicinal plants and I decided to do the course of Pharmacy. In this course, the Professor of Instrumental Analysis, João Batista, who was a PhD student at the “Instituto Militar de Engenharia” (IME) in Rio de Janeiro, convinced me to obtain a Master's degree in Chemistry.

In the experimental Master's work, guided by Professor Richard Hollins, I worked on organometallic reactions with thallium. Because thallium is a very toxic element and its NMR spectra have non-standard NMR characteristics, I was trained to do my own spectroscopic analysis. In my doctoral program, under the guidance of Professor Peter Seidl, I began to work even further with NMR (carbon 13), in the development of rapid and non-destructive methods to determine the content and quality of oils in intact seeds. The purpose of these studies was to find high quality seeds for the production of biodiesel (pro-oil) and also to study the metabolism of these seeds in vivo during germination.

At this time, in the late 1970's, pulsed-NMR instruments were one of the few analytical instruments controlled by computers. In these instruments, the computer was also used to perform the Fourier transform of the data acquired in time domain. Since the electronics of integrated circuits was a technology still in its infancy, it had many technical defects. With this, the NMR instruments needed a lot of corrective maintenance, which was very expensive. So, I decided to do postdoctoral work at the University of Pennsylvania in the group of Professor Stanley Opella, who developed his own NMR spectrometers. In the postdoctoral work, in addition to doing the experimental part in solid-state NMR analysis of virus structure, I started to study electronics and helped with the construction and maintenance of the various home-made spectrometers in the laboratory.

Dr. Luiz Alberto Colnago and R&D FIT director at the Embrapa laboratory

Upon returning to Brazil, I spent a brief period as a teacher at the “Instituto Militar de Engenharia”, and then I joined the newly created Research and Development Support Unit for Agricultural and Livestock Instrumentation (UAPDIA), currently Embrapa Instrumentation, in São Carlos (SP, Brazil). In this unit, I began to develop general instrumentation and, in the second year, I began to develop a low field NMR spectrometer for non-destructive determination of the oil content in corn seeds, under the order of Professor Geraldo Toselo, from the Department of Genetics of the “Luiz de Queiroz” Superior School of Agriculture (Esalq), a unit of the University of São Paulo (USP) in Piracicaba, SP, Brazil. This instrument was totally designed and built in the laboratories of Embrapa. We developed the magnet, the transmitter, the receiver, NMR probes, computer interface and the data processing and control software. Then I started to develop a

prototype of a new NMR spectrometer, funded by the Brazilian Innovation Agency (Finep). This prototype was transferred to a private company, *Gil Equipamentos Industriais*, which started the serial production of this instrument. However, because of the high cost of this device at that time, and the lack of specialized personnel in the research and development laboratories, this company sold four instruments. With the knowledge acquired in the construction of this spectrometer, I started to make instrumentation dedicated to the development of new high-speed analytical methods that could not be performed on existing commercial spectrometers. Currently, these methods are being incorporated into the productive sector by a new Brazilian company, Fine Instruments Technology (FIT), which has already sold tens of low field NMR spectrometers to companies in Brazil and abroad.

For you, what has changed in students' profile, ambitions and performance since the beginning of your career?

At the beginning of my career, Brazil was still crawling in science and only a few universities offered Masters and, more rarely, Doctoral programs. Most university professors did not hold a Master's degree, much less a PhD degree. Thus, the job market for Masters and PhDs as professor-researchers at universities or research institutes was very broad. In many cases, PhDs could be hired for "notorious knowledge" without public tender. Since then, scientific research has multiplied hundreds of times and Brazil is already moving toward the stage of scientific maturity.

Postgraduate programs have increased greatly in the country. According to data released in 2016 by the Center for Strategic Studies and Management Science (CGEE), a study center linked to the Brazilian Ministry of Science, Technology, Innovation and Communications (MCTIC), Brazil formed about 50,000 Masters and approximately 17,000 Doctors in 2014, which is five times more than it was in 1996.

However, the low economic development in Brazil and the consequent difficulty of placing new graduates in the labor market, have led many graduates to enroll in postgraduate courses, even if they do not have the desired profile for a scientific career. However, it has not been easy to get a job, even though you have a PhD degree. This is because state universities or even private universities and research institutes already have their professors-researchers with PhD degrees practically complete. In addition, a very small number of postdoctoral fellowships are being offered, which has led many PhDs to work in subemployments, which sometimes do not even require a high school course.

Could you briefly comment on recent developments in agribusiness research, considering your contributions?

I consider the introduction of new methods of low field NMR for rapid and non-invasive analyses of food and other agricultural materials is the main contribution of the research group I coordinate. We have already shown that the low field NMR has the potential to rapidly determine some food properties, such as the degree of sweetness of a fruit or even the juice potential that this fruit, even without touching it.

What are your lines of research? Could you exemplify a few of them?

My main lines of research involve the use of NMR in practically all its core areas, such as low field NMR relaxometry, high resolution NMR spectroscopy in solids, liquids and heterogeneous materials, and NMR imaging, known as magnetic resonance imaging. Besides the applications in issues involving agriculture and livestock, we also carry out studies of physical and chemical phenomena induced by the magnetic field of the spectrometers.

Recently, we observed that when analyzing electrochemical reactions in situ by NMR (EC-NMR),

Dr. Luiz Alberto Colnago and the low field NMR spectrometer developed by him, at the Embrapa lab

the reactions in this condition are much faster than reactions performed outside the spectrometer. This increase in the reaction speed occurs because of the simultaneous presence of the electric field of the electrochemical system and the magnetic field of the spectrometer. When these two fields are present, the magnetic hydrodynamic effect (MHD) is obtained, which causes the reaction medium to move similarly to mechanical agitation. With this, the electrochemical reaction inside the NMR spectrometer becomes much faster than outside it.

Do you stay informed about the progress of scientific research in Brazil? For you, what are the latest advances and challenges in scientific research in Brazil?

As I said earlier, scientific-academic research has made great advances in the country over the past 30 years. Nowadays, we have developed studies in practically all areas and subareas of knowledge. However, there is still little scientific and technological research in private companies, which leads Brazil to continue importing most technologies in the industrial sector.

Could you briefly describe NMR technology?

NMR is a spectroscopy technique based on the absorption of electromagnetic radiation in the radio frequency region. The main difference between NMR and spectroscopy in the visible, ultraviolet and infrared regions is that the observation of the sample signal must be subjected to a magnetic field so that the energy levels are separated. In addition, the separation and width of the spectral lines and the detection limits are dependent on the strength of the magnetic field. Thus, a spectrometer with high resolution and low detection limit operates with high magnetic field, which is only achieved with superconducting magnets. These magnets have to be continuously cooled with liquid helium, which is an imported and expensive material, a factor that leads to one of the main difficulties of maintaining this kind of spectrometer in Brazil.

In this way, we opted for the construction of low field instruments, with permanent magnets, which are cheaper and with lower maintenance costs. In these instruments, we do not have the spectral resolution necessary to see the different absorptions due to the chemical differences in the molecules, nor the limits of detection of the superconducting devices. Therefore, the low field analyses are based on the relaxation times and the use of large volume and mass samples

“... we opted for the construction of low field instruments, with permanent magnets, which are cheaper and with lower maintenance costs ...”

such as whole fruits and processed foods of up to hundreds of grams. For example, relaxometry can be used to determine the sweetness of a fruit, since the relaxation of water in a sweet fruit is usually much less than the relaxation of water in a fruit that is not sweet. The relaxation of fat in meat is also quite different from the relaxation of water in the same meat, and this can be used to quantify the fat content in a piece of meat, even if it is in a package.

In your opinion, will there be more investment in biodiesel production or will fossil fuel consumption continue?

The first time I worked with biodiesel in the early 1980s, the use of biodiesel was mainly based on the economic and strategic aspects, because of Brazil's heavy dependence on imported oil, which was very expensive. With the fall in the price of oil in the following years, the Brazilian program for biodiesel was extinguished, but this program has resurfaced in the last decade because of the importance of using biodiesel for the environment. In addition to the economic and strategic aspects, the need to search for renewable and less polluting fuels was highlighted. Thus, I believe that the production and commercialization of biodiesel will not end while much of the transportation of consumer goods and people is carried out by diesel-powered vehicles in Brazil. I believe that the biodiesel/diesel mix, with a

higher proportion of biodiesel, should occur in the region of the country where the raw material, mainly soy, is produced, that is, in the Midwest. This would minimize both the transportation cost of diesel to the biodiesel-producing regions, and the transportation of biodiesel to all regions of the country. That is, the use of biodiesel would have greater economic advantage.

Today, what is the path Brazil should take to produce biodiesel? Is it still soybeans?

I believe that there is currently no viable alternative to large-scale biodiesel production other than soybeans. Although soybeans produce less than half a ton of oil per hectare, it is a crop that extends to all regions of Brazil, and there is already a great deal of knowledge about its entire production chain. Other options could be: the palm tree called “dendzeiro”, from which the “dendê” oil is extracted, which has

“I believe that there is currently no viable alternative to large-scale biodiesel production other than soybeans.”

high productivity, but has high water demand and is limited to the Amazon Region; macaúba, another palm tree with high potential for producing vegetable oil, can be grown in all regions of the country; however, it still needs a lot of research and technology to achieve large-scale production and could replace soy.

You have received some awards. What is it like to receive this kind of recognition? What is the importance of these awards in the development of science and new technologies?

Yes, I received awards from scientific societies and the Brazilian Legislative Power. Awards are always an incentive, not only for those who receive them, but also for researchers who seek to have their work recognized at some point. So, awards are very important in any area of science. I believe that the award/recognition of the work of researchers and professors is far below what would be desired.

Even with the difficulties of doing research in a developing country such as Brazil, there are many important studies being carried out in our country, and they are not always recognized by the academic community, civil society or federal agencies. Each award granted to a researcher arouses in many young people the desire to also receive recognition. With this, talents so necessary to research can be attracted to scientific and technological areas.

For you, what is the importance of the support of funding agencies for the scientific development of the country?

In a country with scarce private incentives, the state development agencies are practically the only sources of resources for scientific and technological research. There would be no research in Brazil without the contribution of agencies such as the National Council for Scientific and Technological Development (CNPq), the Coordination for the Improvement of Higher Education Personnel (CAPES), the Brazilian Innovation Agency (FINEP) and the State Research Foundations (FAPs). The State of São Paulo Research Foundation (FAPESP) has reduced, but has not stopped, funding good research projects even in critical periods of the economy. The maintenance of funding, although at levels lower than necessary, is the only way to give survival to the research of the country, producing new researchers and generating new advances in knowledge. The breakdown of this financing chain is one of the main problems of research in Brazil.

At the moment, the investment in scientific research in Brazil is being reduced. How do you see this situation, and what would you say to young researchers?

Federal investment in research and development in Brazil has always faced oscillations, with short periods of high investment and long periods of low investment. From 2004 to 2013, mainly, we observed that the Federal Government invested heavily in scientific research, with great renovation and expansion of laboratories and research centers throughout the country, and great investment in

the training of personnel, including training abroad. In this period of strength, the country received hundreds of scientific delegations from developed countries, who sought collaborations in the most varied areas of knowledge. The great amount of equipment in the laboratories and the great facility for obtaining resources for research and for the training of personnel impressed the visitors. However, there is currently a resource constraint, both for the maintenance of the implanted infrastructure and for the provision of research grants to follow the continuous flow of personnel training.

Currently, there are a large number of Masters and PhDs (about 70,000) graduated annually in the country, who are having difficulty working in their areas and who sometimes accept underemployment. Practically, there are no jobs in public and private universities for newly graduated PhDs, just as there are few jobs in industries and service areas for researchers/PhDs.

However, just regret is not enough. During crises, great advances are made. With the falling employability rate, one way would be to invest in innovative entrepreneurship, even with all the challenges of Brazil's costs, such as bureaucracy, high cost of credit and other difficulties. To boost these initiatives, federal agencies could offer incentives with subsidized or non-refundable resources, as does FAPESP for many technological innovation projects in São Paulo State. Investment in creating innovative small companies, which is becoming a trend in Brazil, is one of the most important ways to increase the employability of most of the PhDs being prepared in the country.