Impact of cell wall and polyphenol composition on the texture of banana and yam products produced after heat processing

I. Context

Strengthen the food security in South countries is necessary in particular for starchy products such as roots, tubers and bananas (RTB) which are staple foods for South populations. Many varieties of RTB, resistant to diseases and pests or with high carotenoid contents for eg., developed by national and international breeding programs (cassava, sweet potato, yam, cooking banana, potato) have serious problems of acceptability and adoption by the main actors in RTB value chains in Africa. Consumer acceptability is the key for improving the nutritional quality of RTB products. It is therefore important to provide to breeders tools allowing them to improve the creation and selection of hybrids based on the expected sensory quality. The thesis will be part of the "Breeding RTB products for end user preferences (RTBfoods)" project funded by Bill and Melinda Gates Fondation which aims to identify essential quality traits for users and consumers across a wide range of basic food products and to establish varietal selection methods of these quality traits to meet the expectations of users. Specifically, the thesis will focus on boiled yam and banana, which are staple food in West Africa.

Among the sensory criteria, texture is a primary quality factor for yam and banana products, followed by color, flavor and digestibility. The texture quality of boiled yam and banana end-products depends on the initial characteristics of raw material and on processing techniques (Otegbayo et al., 2005; Akissoe et al., 2011; Gafuma et al., 2018). Yam tuber hardness or mealiness after boiling could be due to cell wall thickening, permeability changes of the cell wall and of the cell adhesion (Otegbayo et al., 2005; Akissoe et al., 2011), and/or lignification-like mechanism involving phenols (Medoua et al., 2005; Medoua et al., 2006) but the relationship with cell wall and polyphenol structure and composition still remains to be detailed as the changes in the composition during and after cooking are only partially established.

Cooking resulted in pectin solubilisation and middle lamella dissolution leading to cell wall separation, and small pectin size has been hypothetized to favour a softer texture of boiled banana (Qi et al., 2000), and a high initial dry matter content a higher firmness (Gibert et al., 2010) in relation to starch gelatinization. While textural properties can be predicted by titratable acidity and dry matter content, predictions of mealiness and adhesiveness were not efficient (Bugaud et al., 2013) and certainly need new investigations (soluble pectic polysaccharides, and active tannins). For banana no significant change in total phenolics was observed in the pulp after boiling with or without peel (Passo-Tsamo et al., 2015), while regarding individual phenolic compounds, the most important change in the pulp was the increase of ferulic acid.

Raw Banana and yam texture is probably determined by a few structural factors: dry matter, starch and cell wall content. However there is little knowledge on the link between the texture of boiled banana and yam and the original RTB as much information is still lacking since in most of the available literature the composition of fresh and boiled yam and banana were evaluated separately without establish the link between them.

References:

Akissoe et al. (2011) LWT - Food Science and Technology, 44, 321-329.

Bugaud et al. (2013) Postharvest Biology and Technology, 84, 1-8.

Gafuma et al. (2018) Journal of Food Research, 7, 98-111.

Gibert et al. (2010) Journal of Food Engineering, 98, 471-479.

Medoua et al. (2005) Food Research International, 38, 143-149.

Medoua et al. (2006) Food Research International, 39, 513-518.

Otegbayo et al. (2005) Journal of Texture Studies, 36, 324-332.

Qi et al. (2000) Journal of Agriculture and Food Chemistry, 48, 4221-4226.

Passo Tsamo et al. (2015) Journal of Food Composition and Analysis, 44, 158-169.

II. Thesis objective

The aims of this PhD project are to:

1) Evaluate the impact of the cell wall polysaccharides composition, particularly of pectin structure, and polyphenol composition on the softening during boiling of banana and yam.
2) Identify the biochemical mechanisms involved during boiling determining textural properties of banana and yam products, and underlying the variability of response of bananas and yams during boiling, with a particular focus on cell wall polysaccharides and procyanidins.

III. Time schedules and research methodology

The multi-dimensional aspect of the systems requires assessing both the raw RTB crops composition (e.g. dry matter content, starch content, pectins and cell wall components, etc.) and the final products characteristics (e.g. composition, cooking characteristics, texture, etc.).

First, to test the hypothesis that cell wall polysaccharides, pectin and polyphenol composition influence cooking ability and texture of banana and yam products, we will use a multi-varietal approach. About 2-8 varieties of yam roots and banana fruits (Cavendish and cooking bananas) samples carefully chosen among known varieties with contrasted cooking and browning properties, and already characterized in terms of starch and amylose content, will be boiled using standardized procedures and characterized in terms of textural properties. Two maturation stages will be used for banana (green and yellow) in order to obtain banana with or without starch and pectins of different structures. Cell wall polysaccharides and soluble pectins will be extracted from raw and processed bananas and yams and deeply analyzed. To do so, protocols generally used for cell wall extraction and analysis will be adapted to banana and yam products. In particular this will require the establishment of a method for destarching.

Cell wall and pectin composition, pectin molar mass distribution, methylation and acetylation degree, and starch will be determined by means of chromatographic and spectroscopic techniques (GC-FID, GC-MS, HPSEC-MALLS, UV-vis). The activities of main endogeneous pectolytic enzymes (PME, PG) will also be determined in fresh RTBs as they could be an explanatory factor in texture loss upon processing. The macrostructure (thickness, porosity) of the cell wall will also be determined by means of microscopy, spectroscopy and NMR techniques.

Total polyphenols and more specifically procyanidins, and ferulic acid in banana, will be characterized in order to determine their impact on texture. The composition, DPn and polydispersity of procyanidins will be determined using thioacidolysis and reversed phase HPLC-DAD, UPLC-DAD-MS and HPSEC-MALLS.

In a second step, we propose to build models in order to better understand the mechanisms involved during cooking. pH varies with variety and maturation in banana fruits, it could have an impact on pectin degradation during cooking. In order to study this impact, we will biochemically enrich the initial matrix to control its pH and thus to evaluate the impact of pH on the texture and composition of the final product (boiled banana). To do so Cavendish and plantain cylinders will be boiled in water after previous inbibition with citrate or not. This will first require the development of a method for the acid enrichment. This biochemically modified matrix will then be characterized in terms of textural properties and cell wall polysaccharides extracted and analyzed, as in the first step.

IV. Expected results

The expected results are the development of cell wall extraction and analysis methods adapted to yam and banana products; an overview of the variability of polysaccharide and polyphenol composition of raw and boiled yam and banana products; impact of cell wall polysaccharides, pectin and procyanidin composition on the cooking ability and texture of boiled banana and yam, and the identification of key traits and key mechanisms determining texture of banana and yam boiled products.

Key words: Cell wall analysis, pectin, banana, plantain, yam, texture, cooking ability, polyphenol, procyanidin.

Scientific framework and supervision:

PhD school: Ecole doctorale 536 Agrosciences et Sciences, Université d'Avignon.

Thesis co-directors: Agnès Rolland-Sabaté, Carine Le Bourvellec.

Duty station/Research Unit: UMR408 Sécurité et Qualité des Produits d'Origine Végétale, INRA, Université d'Avignon, Avignon (south of France) ; Quality and Process team. http://www6.paca.inra.fr/sqpov

The thesis is co-funded by INRA and "RTBfoods" project; the salary will be of approximately 1400 € / month.

Candidates profile:

The candidates must have a master degree (or equivalent) in physico-chemistry, quality of bioproducts, food sciences or material sciences and have to be interested in bio-polymers and to be able to speak and write in English. He/she has validated competences in one or more of the following topics: food biochemistry, physico-chemical techniques, structural characterization, rheology.

A B1 french level is also necessary to obtain the residence permit for non-EU citizens.

Application form:

Dead line: 6th of december 2019. Applications must be sent to: agnes.rolland-sabate@inra.fr

The application must contain the following documents:

- CV (current situation, curriculum, diplomas obtained, subject of research placement, level of English, level of French for non-French speakers) ;
- 2 letters of appreciation, including one from the supervisor of the master course;
- Letter of motivation, adapted to the subject and showing the adaptation of the profile of the candidate to the proposed subject.

The thesis will start the 2nd of january 2020.

Lab description:
The Joint Research Unit (UMR) Sécurité et Qualité des Produits d'Origine Végétale (SQPOV) of INRA Avignon aims to contribute to the re-conception, in a perspective of sustainable food, of processes for fruit and vegetables to improve nutritional quality, by optimized processes respecting the microbiological safety of these products, and for a total valuation of the biomass used. The Quality and Process team focuses on the understanding of phenomena induced by cooking and by tissular fragmentation of fruit and vegetables during processing, notably in terms of macromolecules interactions: phenolics, cell wall polysaccharides, enzymes, etc. A crucial property is texture, both as a complex functional property of this filled cellular tissue (as a marker of treatment intensity) and as an organoleptic property of importance to the consumer.

Some team publications related to the topic:
Brahem, M., Renard, C., Gouble, B., Bureau, S., & Le Bourvellec, C. (2017). Characterization of tissue specific differences in cell wall polysaccharides of ripe and overripe pear fruit. Carbohydrate Polymers, 156, 152–164.

Le Bourvellec, C., Bouzerzour, K., Ginies, C., Regis, S., Ple, Y., Renard, C. (2011). Phenolic and polysaccharidic composition of applesauce is close to that of apple flesh. Journal of Food Composition and Analysis, 24, 537-547.

Le Bourvellec, C., Watrelot, A., Ginies, C., Imberty, A., & Renard, C. (2012). Impact of Processing on the Noncovalent Interactions between Procyanidin and Apple Cell Wall. Journal of Agricultural and Food Chemistry, 60, 9484-9494.

Perez, E., Rolland-Sabate, A., Dufour, D., Guzman, R., Tapia, M., Raymundez, M., Ricci, J., Guilois, S., Pontoire, B., Reynes, M., & Gibert, O. (2013). "Isolated starches from yams (Dioscorea sp) grown at the Venezuelan Amazons: Structure and functional properties." Carbohydrate Polymers 98(1): 650-658.

Renard, C., Watrelot, A. & Le Bourvellec, C. (2017). Interactions between polyphenols and polysaccharides: Mechanisms and consequences in food processing and digestion. Trends in Food Science & Technology, 60, 43-51.

Rolland-Sabaté A. (2017). High-Performance Size-Exclusion Chromatography coupled with on-line Multi-angle Laser Light Scattering (HPSEC-MALLS). In Advances in Physicochemical Properties of Biopolymers, Martin Masuelli & Denis Renard Eds., Bentham Science Publishers, pp 95-141.

Rolland-Sabaté, A., Guilois, S., Jaillais, B., & Colonna, P. (2011). Molecular size and mass distributions of native starches using complementary separation methods: Asymmetrical Flow Field Flow Fractionation (A4F) and Hydrodynamic and Size Exclusion Chromatography (HDC-SEC). Analytical and Bioanalytical Chemistry, 399, 1493-1505.

Rolland-Sabate, A., Sanchez, T., Buleon, A., Colonna, P., Ceballos, H., Zhao, S., Zhang, P., & Dufour, D. (2013). Molecular and supra-molecular structure of waxy starches developed from cassava (Manihot esculenta Crantz). Carbohydrate Polymers, 92, 1451-1462.

Short presentation of the umbrella project funded by Bill and Melinda Gates Fondation, for which this thesis shall be attached to:
The thesis will be part of the "RTBfoods" project supported by Bill and Melinda Gates Fondation entitled "Breeding RTB products for end user preferences". The "RTBfoods" project aims to identify essential quality traits for users and consumers across a wide range of basic food products and to establish varietal selection methods, integrating a high-throughput screening by spectral analysis of these quality traits to meet the expectations of users. Multidisciplinary research teams of social scientist and food technologists, in chemometrics, plant breeding, genetics and disclosure work together to achieve this goal. This RTBfoods project is coordinated by CIRAD (UMR QUALISUD) and involves 15 research centers (BIOVERSITY, BOWEN University, CARBAP, CNRA, CIAT, CIP, IITA, JHI, NACCRI, NARL, NRCRI, NRI, UAC/FSA, INRA, CIRAD) in 14 countries. Specifically, the thesis will participate to WP2 on Biochemical characterization of Quality Traits in which Standard operating procedures (SOPs) are used by partners to characterize and understand key user preferred traits.