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Diversity, use and consumers´ acceptance of banana cultivars in the Peruvian Amazon: the case of Pucallpa

MASTER'S THESIS

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Author: Bc. Petr Pudil

Supervisor: doc. Ing. Zbyněk Polesný, Ph.D.

Declaration

I hereby declare that I have done my thesis “Diversity, use and consumers´ acceptance of banana cultivars in the Peruvian Amazon: the case of Pucallpa” independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 27th April, 2018

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Petr Pudil

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Czech University of Life Sciences Prague
Faculty of Tropical AgriSciences

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Abstract

Bananas represent large part of local food basket in many tropical countries. Though it is a crop with high intraspecific diversity, local cultivars in many regions have not been characterized in terms of morphology, local use and consumers' acceptance. The study was conducted in Pucallpa, the administrative centre of the Ucayali department located in the Peruvian Amazon, which is one of the most important regions in terms of banana production in Peru. A market survey of seven main markets in the town was done in order to inventory all *Musa* cultivars. The cultivars were then morphologically characterized using previously published descriptors and their weight measured. Subsequently, the vendors and customers were interviewed in order to document local knowledge including vernacular names, modes of preparation and use patterns of particular cultivars. Sensory properties and overall acceptance evaluation of dessert-type bananas was performed using local consumer panel.

Eleven distinct cultivars were found during the market survey, five cooking ('Bellaco', 'Campeón', 'Común', 'Mamaluca' and 'Sapucho') and six dessert cultivars ('Capirona', 'Isla', 'Manzano', 'Muquicho', 'Rojo' and 'Seda'). According to our best knowledge, one of the cultivars investigated ('Campeón') has been newly documented in Peru. The highest peel to pulp ratio was found in three dessert cultivars, 'Muquicho', 'Manzano' and 'Seda'. The highest overall acceptance was performed by 'Seda', 'Muquicho' and 'Manzano'. The overall acceptance of 'Seda' was significantly higher compared to the other cultivars. In most of the cultivars was observed positive correlation between sweetness and overall acceptance. It can be partially explained by young age of the panellists, as younger people tend to evaluate sweet products better. Cultivars with yellow-orange colour of flesh 'Isla', 'Mamaluca', 'Muquicho', 'Rojo', and 'Seda' should be further studied as potential sources of provitamin A. Vitamin A deficiency manifests by supressed immunity, dry skin and hair, or by night blindness. In pregnant women, it can have even detrimental effect on brain development of the foetus. This form of hidden hunger can be prevented by consumption of enough provitamin A rich food, such as fruits with orange or red flesh, which includes certain banana cultivars.

Key words: banana, sensorial properties, traditional knowledge, human nutrition, intraspecific diversity

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List of the abbreviations used in the thesis

ASTM	American Society for Testing and Materials
BBrMV	Banana bract mozaic virus
BBTV	Banana bunchy top virus
BSV	Banana streak virus
CABI	Centre for Agriculture and Bioscience International
CIA	Central Intelligence Agency
EAHB	East Africa highland bananas
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
IIAP	El Instituto de Investigaciones de la Amazonía Peruana
IICA	Instituto Interamericano de Cooperación para la Agricultura
INEI	Instituto Nacional de Estadística e Informática
INIBAB	International Network for the Improvement of Banana and Plantain
IPGRI	International Plant Genetic Resources Institute
OGTR	Office of the Gene Technology Regulator
TR	Tropical race
UNIA	Universidad Nacional Intercultural de la Amazonía
UNU	Universidad Nacional de Ucayali

1. Introduction

The Amazon rainforest was providing livelihood for indigenous Amazonians for millennia without any obvious sign of environmental degradation, while they were practicing small scale slash-and-burn agriculture (Alcorn, 1995). After the European conquest, it has become an object of over-exploitation. Permanent settlements grew and forests were largely replaced by commercial crops, such as rubber tree [*Hevea brasiliensis* (Willd. ex A. Juss.) Müll.Arg.] or soy bean [*Glycine max* (L.) Merr.]. Agricultural expansion is still the primary driver of tropical deforestation (Geist & Lambin, 2002). Beside decimation of native populations, this has resulted in decrease of natural biodiversity and agricultural value of the region (Geist & Lambin, 2002; Nunn & Qian, 2010; Oliveira et al., 2013; Rodrigues et al. 2013). The area possess large diversity of agricultural and forestry products. Many plants introduced after the European conquest have become inseparable part of the local food basket, banana being one of them (Nunn & Qian, 2010).

Musa, a genus producing popular climacteric fruits, bananas and plantains, originated in Southeast Asia and has become a main food crop for millions of people and an important source of income from international trade, not only in the Amazon rainforest but in the tropics worldwide (Frison & Sharrock, 1998). Bananas and plantains, consisting of fibrous peel and highly caloric pulp, are great sources of energy. Moreover, the pulp is rich in minerals vital for human health, such as potassium, magnesium or calcium (Forster et al., 2003) and vitamins: A, B_6, C and D (Sampath et al., 2012).

Inadequate micronutrient intake resulting in hidden hunger is not uncommon in both, developed and developing countries (Biesalski, 2017). Latin America is not an exception, including Peru (Lechting et al., 2009; López et al., 2015). Bananas, wild species as well as cultivars, are plants with twin value of food and medicine, representing inexpensive, available and versatile food resource capable of improving both nutrition and health of local people (Malla et al., 1982).

2. Literature Review

2.1. Importance of *Musa*

Genus *Musa* consists of various herbaceous species. Those for human use are mostly used as edibles, and some species for constructions and decorations. Their most important product is fruit. Its attractiveness and nutritive composition made it one of the most favourite fruit worldwide.

Nowadays produced in more than 100 countries, the world annual production was 148 million tons in the year 2016 (FAO, 2017). Most of it was produced in Southeast Asia, while fruit for export is rather produced in Latin America and the Caribbean. It is then exported to the United States, European Union, Russian Federation, Japan and other countries. The biggest exporter worldwide is Ecuador, Peru´s northern neighbour, which produced 7.1 million tonnes of bananas and plantains in the year 2016 (FAO, 2017). Peru itself produces around 2.5 million tons of bananas and plantains annually, less than export-oriented Latin American countries, and it is consumed mostly there (FAO, 2017). East of the country, lying in the Amazon basin and including the region of Ucayali, is the second most important region for *Musa* fruit production in Peru (Krauss et al., 1999). Banana is one of the most commonly planted crops in the catchment area of the Ucayali River, having great local economic importance (Labarta et al., 2007).

2.2. *Musa* plant

2.2.1. Botanical description

Plants of the *Musa* genus are monocotyledons, classified in the family Musaceae, within the order Zingiberales. They are arborescent herbs, showing no signs of lignification or secondary thickening of their pseudostem (Tomlinson, 1969). Aboveground parts are sometimes protected by epicuticular wax. Cultivated *Musa* usually reaches from two to six metres. The tallest species of the genus, *Musa ingens* N.W. Simmonds, reaches up to 15 metres (OGTR, 2008).

The pseudostem consists of tightly wrapped leaf sheets in many spirally-arranged layers (See Figure 1.). The large green leaves are petiolate, they have entire leaf blade with pronounced mid-rib and pinnately arranged parallel veins. Young leaves are light green, tube-like rolled upon emergence. They are almost vertical when they emerge and later they get horizontal and eventually drooping. Leaf blade can be almost four metres long and one meter wide. Leaf margins usually tear along the veins in windy conditions. Petioles are mostly dark or light green, sometimes yellow or red (Daniells et al., 2001).

Rachis (fruit stalk) emerges at the end of true stem, growing in the centre of the pseudostem. Inflorescence is formed at the top. Immature inflorescence is hidden inside bell (heart), consisting of purple, red or yellow bracts. During flowering, one bract opens and reveals the flowers each day. Inflorescence consists of female, male and neutral flowers. Female flowers are located along the upper inflorescence. The fruits develop from their ovaries later. Neutral flowers are bellow, if present at all, and male flowers are along the lower inflorescence, infertile in edible cultivars and often shed during fruit development (Nelson et al., 2006).

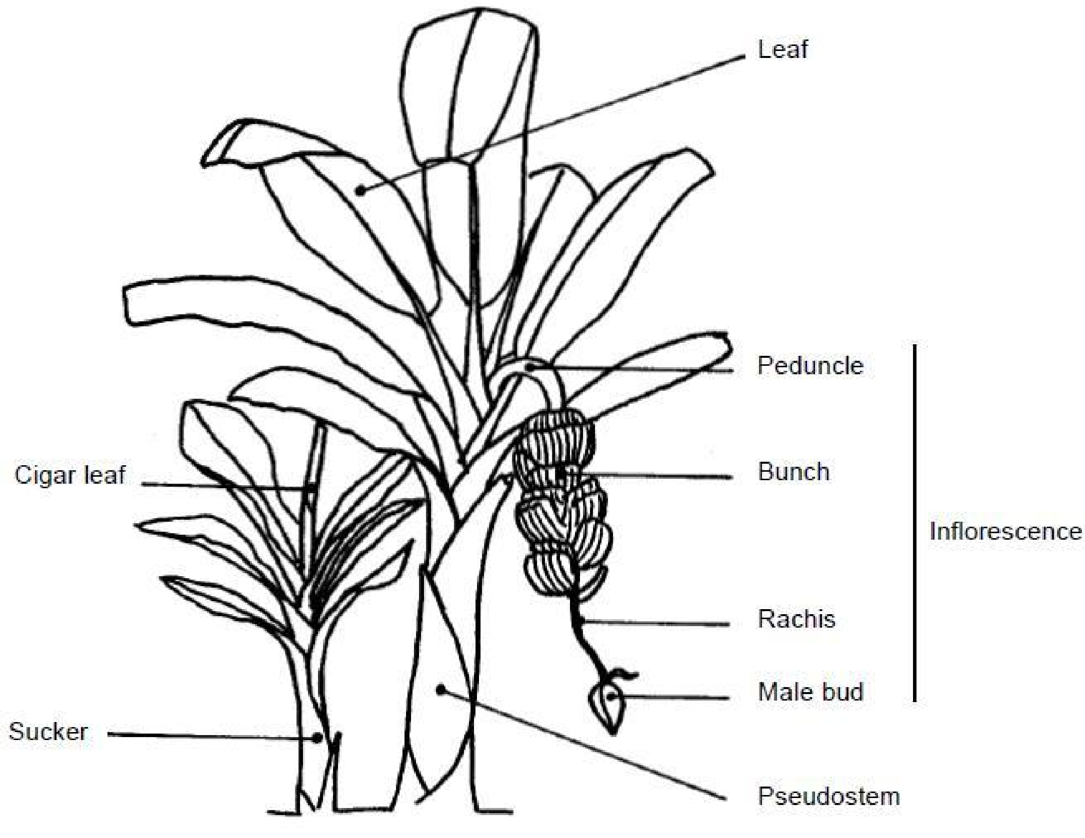

Figure 1. Musa plant description (adapted from Champion, 1963)

The fruit is a berry, called commonly a finger. Fruits are negatively geotropic, which means they turn upwards as they develop. Fingers are connected into hands, and all hands together on rachis create a bunch. Numbers of fingers in one hand and hands in a bunch vary according to cultivar and local conditions. The protective layer of fruit is called peel. In the case of banana, it is a fusion of the hypanthium, exocarp and pericarp. Peel covers pulp, which originates mainly from endocarp (Simmons, 1953). Edible *Musa* cultivars have fleshy, seedless pulp while the wild species have less flesh and contain many ovoid black or brown seeds (Morton, 1987; Nelson et al., 2006).

Bellow ground is starchy corm producing suckers. Root system is dense, and reaches 1.5 metre deep. *Musa* plant root system prefers well-drained, deep and fertile soils (Nelson et al., 2006).

2.2.2. Taxonomy

Genus *Musa* is relatively small. It contains 72 species and some more subspecies and varieties of mainly forest-dwelling herbaceous plants (Royal Botanic Gardens, Kew and Missouri Botanical Garden, 2017). Practically, there are many different taxonomic levels and approaches in the genus. In the local folk taxonomies, there are names for *Musa* in general, names for cultivars and cultivar groups or groups of cultivars sharing particular features (Gerda, 2000). Local cultivar name usually reflects some of the various properties, such as the plant morphology, look or the main use (Hunn, 1982).

Scientifically, there are several unresolved issues in the taxonomic classification of different varieties, as well as inconsistencies in the number of species included in the genus. Taxonomy of modern cultivars is confused by many factors, e.g. sterility, ancient domestication, hybrid origins and subsequent temporal genetic separation. (Heslop-Harrison & Schwarzacher, 2007).

Cheesman (1947) divided *Musa* into four sections (taxonomic rank below the genus and above the species level), based on the chromosome numbers and morphological characteristics: Australimusa and Callimusa with chromosome number 2n=2x=20, and Rhodochlamys and Eumusa (2n=2x=22). All edible cultivars are derived from the latter one, except Fe´i group originating partially in the Australimusa section. Later, Argent (1976) created section Ingentimusa for species *M. ingens* with chromosome number 2n=2x=14.

Cultivar taxonomy requires different approach than botanic taxonomic groups in *Musa*. The simplest division of edible bananas is into dessert and cooking-type cultivars. There is no clear botanical division between those groups (Heslop-Harrison & Schwarzacher, 2007), they are artificial and used for practical reasons only (Cheeseman, 1948). Generally, we can say that dessert cultivars are mostly eaten raw at a fully ripe stage of maturity and cooking cultivars are starchy and rather thermally processed before serving – either ripe or unripe (Gibert et al., 2009). Still, they can be used in very similar way. For example, some dessert bananas are cooked unripe and some cooking ones used in a way like dessert bananas when they are ripe.

The most common system of cultivar taxonomy used nowadays was developed by Simmonds and Shepherd (1955), it says that cultivars originated from wild species *Musa acuminata* Colla and *Musa balbisiana* Colla, both diploids with genomic constitution AA and BB respectively. Edible cultivars are mostly polyploids and/or hybrids (*Musa* × *paradisiaca* L.). Robinson (1996) suggested that the A genome is responsible for the genes for parthenocarpy and yield, while the genome B bears the genes for high starchiness, drought tolerance and hardiness.

Some edible banana cultivars have an AA, AB or eventually BB genotype, but the vast majority are AAA, AAB or ABB triploids. AAA cultivars, derived only from *M. acuminata* dominate the world trade, but globally, AAB and ABB are of higher importance as they are grown in the tropics as staple food for millions of locals (Singh et al., 2014). Genome BBB is rather rarity in cultivated varieties (Wu & Kress, 2000). Beside of those, there are also cultivated tetraploids AAAA, AAAB, AABB and ABBB. Most of them were created by breeders recently to reach higher pest and disease resistance (Daniells et al., 2001).

On lower taxonomical level, we could recognize subgroups in triploid genomic group AAA and AAB. AAA group consists of Cavendish, Gros Michel and EAHB subgroups. AAB group consists of Plantain, Silk, Pome, Mysore and few other subgroups (ProMusa, 2018).

2.2.3. Diversity

It is estimated that there is more than 1,000 cultural banana varieties worldwide (Li et al., 2013). Diversity of *Musa* cultivars was assessed in some regions in previously published studies. The area between Southeast Asia and the Pacific, as the origin centre, is home to numerous cultivars. Arnaud and Horry (1997) depicted more than 200 cultivars from Papua New Guinea; Hapsari et al. (2017) found and described 79 cultivars in Indonesian Eastern Java; Daniells et al (2014) identified 64 distinct cultivars in Salomon Islands, including 9 cultivars from the Fe´i group. Kepler and Rust (2011), after 30 years of work, published a book about *Musa* diversity in Hawaii Islands with pictures and description of 140 cultivars.

African *Musa* diversity was studied as well: Gold et al (2002) identified 130 cultivars in Uganda; 43 cultivars were found in Rwanda by Ocimati et al. (2014); and Sivirihauma et al. (2007) described 48 cultivars in The Democratic Republic of Congo, of which was about 75% was for cooking.

Behrendt (2015) found and assessed 7 various cultivars in valley in the north of Oman, a country which had great connection with the banana growing areas from ever since but tough water conditions. Majority of the cultivars were dessert. De Langhe (2000) presented cultivars from both collections and rural areas of the Middle East: three in Jordan, 16 in Egypt and 31 in Oman, many of them practically not planted by farmers any more. Some varieties occurring in New World were described by Quintero and García (2008), they found 10 dessert and 13 cooking cultivars in Columbia.

More complex *Musa* germplasm catalogue was presented by Daniells et al. (2001) as an educational publication, it contains information on numerous wild species and more than hundred edible cultivars, handily divided into genomical groups. *Musa* cultivars are of such vast variability and disposal that details about many cultivars including their synonyms, use and distribution are still not fully documented. Moreover, beside the intercultivar variability, many cultivars show high intraclonal variability (Krauss et al., 1999).

2.2.4. Chemical and nutritional composition

Chemical and nutritional composition of banana fruit varies greatly according to its type, group, subgroup, cultivar, ripeness and growth conditions. Bananas, consumed in ripe or unripe maturity stage, and both cooked or raw, are important sources of calories, vitamins and minerals. Compared to an apple, banana has higher content of protein, iron, potassium and vitamins (Banerjee et al., 2011). Maturity stage of the fruit has the most crucial effect on its chemical composition (Abdullah et al., 1987). Forster et al. (2003) showed that the composition differs significantly even between parts of the pulp itself.

Carbohydrates constitute from 16 to 54 grams in 100 grams edible portion (Egbebi & Bademosi, 2001; Hapsari & Lestari, 2016). Starch content changes during ripening as it is hydrolysed into sugar. It could be seen in cultivar 'Berangan', which showed significant decrease in starch content between the 8th and the 11th week of ripening, while there was an increase in total sugar at the same time (Abdullah et al., 1987). Sugars are present from 5 to 20 g/100 g of fresh weight. Proteins are present just from 0.8 to 3 g/100g and fats usually less than 0,5g/100 g, exceptionally over 1g/100 g. Water content is between 35 and 80 %, lowest in starchy varieties in unripe maturity stage (Cano et al., 1997; Egbebi & Bademosi, 2001; Yomeni et al., 2004; Coulibaly et al., 2007; Hapsari & Lestari, 2016). Composition of five various samples of banana pulp is listed in Table 1.

Table 1. Composition of various cultivars´ pulp

	Cultivars				
Description and components	'Ambon Hijau' 1)	'Raja Bandung' 1)	Unknown plantain 2)	Unknown plantain 2)	CRBP 14 3)
Type	Dessert	Cooking	Cooking	Cooking	Experimental hybrid
Ripeness	Ripe	Ripe	Ripe	Unripe	Ripe
Water	72.94 %	66.49 %	61.30 %	38.50 %	66.84 %
Ash*	0.78 g	0.82 g	6.00 g	3.80 g	0.71 g
Carbohydrates*	24.33 g	31.13 g	27.24 g	54.00 g	27.01 g
Protein*	1.92 g	1.51 g	3.15 g	2.80 g	0.90 g
Fat*	0.03 g	0.05 g	1.20 g	0.20 g	0.20 g
Total sugar*	15.91 g	20.82 g	12.80 g	5.53 g	
Crude fibre*			1.11 g	0.70 g	
Vitamin C*	19.10 mg	16.45 mg			
Potassium*	275 mg	350 mg			226 mg

* = /100g
(1) Hapsari L & Ayu Lestari D, Agrivita. 38 (2016) 303-311; (2) Egbebi AO & Bademosi TA, Int J Trop Med Public Health. 1 (2001) 1-5; (3) Coulibaly S et al., Tropicultura 25 (2007) 2-6.

Apart of that, bananas are rich in vitamins. They are considered an excellent source of the vitamins B, C, E, antioxidants at the same time, and B_6, a precursor for serotonin (Wall, 2006). Vitamin content is typically higher in unripe fruits, especially in the case of vitamin C (Wills et al., 1984). Vitamin A precursors, carotenoids, are present in large amounts in some cultivars as well. Interestingly, Cavendish subgroup, represented by the most economically important cultivars, is very poor in β-carotene, only 21 µg/100 g (Holden et al., 1999). In contrast to this, some cultivars found in the Southeast Asia contain 300–400 µg/100g. The Pohnpei cultivar 'Karat' had even 867 µg/100 g and the highest β-carotene content was found in cultivar 'Uht en Yap', almost 5,000 µg/100 g, which is 238 times the level found in the 'Cavendish' (Englberger et al., 2003a, Englberger et al., 2003b). Both latter cultivars belong to the Fe´i group, which is known for exceptional provitamin A contents (Englberger et al., 2006).

Bananas were also found to be good source of minerals, especially potassium, calcium and phosphorus, all of them with great importance for proper cell functioning in human body (Sulaiman et al., 2010). Mineral content, as opposite to vitamins, was found higher in ripe fruits, potassium being the major mineral present in both main ripening stages (Wills et al., 1984; Leterme et al., 2006). Beside the main minerals is present also sodium, magnesium, iron, zinc, boron, copper and manganese (Pareek, 2016). Moreover, banana fruit contains many volatile compounds. The most important are esters (Pérez et al., 1997) and alcohols (Nogueira et al., 2003), which play a major role in the fruit aromatic properties and therefore strongly influence consumer´s choices (Taiti et al., 2017).

2.2.5. Propagation

Vast majority of the edible cultivars is unable to propagate sexually as they are parthenocarpic and have sterile male flowers. That does not mean that they never produce seeds but the amount of seeds is very low. Shepherd (1987) showed that the Cavendish subgroup cultivars set seed so rarely they can be considered female sterile. On the other hand, Gros Michel subgroup produced an average of two seeds in one bunch when pollinated by hand (Simmonds, 1966).

Therefore, they are reproduced solely vegetatively: by shoots – suckers, which grow along the motherplant´s pseudostem (Ortiz & Swennen, 2014). Suckers are either negatively selected in small plantation or homegardens, or collected and planted separately on bigger plantations. Large plantations use another method, tissue culture.

Micropropagation offers a good alternative to the conventional propagation, as it provides sufficient number of highly uniform suckers with earlier harvest maturity. Apart from large-scale producers, the method is used for conservation of genetic resources (Israeli et al., 1995). Both of those methods produce genetically identical plants.

2.2.6. Pests and diseases

Banana plantations are under threat from several pests and diseases, some of them with huge global impact. Outbreaks of those pathogenic organisms are much more common in large plantation monocultures than if bananas are grown in smaller numbers spatially separated in agroforestry systems (Nelson et al. 2006). Banana plant pathogens count various insects, fungi, viruses and bacteria. Their pests are numerous aphids, beetles and flies causing damage and spreading other pathogenic organisms. But the most prevalent and dangerous banana diseases are caused by fungi. Attacking all plant parts, fungi diseases account for the largest pre and post-harvest losses.

Fusarium oxysporum f. sp. cubense is the cause of the lethal Panama disease (fusarium wilt), which is a threat worldwide, currently its tropical race four (TR4) (Ploetz, 2006). After fusarium wilt tropical race one (TR1) drastically impacted plantations of 'Gros Michel', they were replanted with Cavendish subgroup cultivars in the late 1950s. *Fusarium* was not longer a major thread until the TR4 appeared and spread (Ploetz, 2004). It was discovered for the first time in Taiwan in the 1990 and did not expand outside of Asia for next approximately 20 years (Buddenhagen, 2009). *Fusarium* affects Cavendishes strongly but it is not restrained just to them. It infects numerous cooking and dessert varieties, around 80 % of all cultivars are considered susceptible to Fusarium wilt (Ploetz, 2004). Therefore, the Panama disease has become a problem threatening both export production and local food security. It infects plants through their roots, continuing into pseudostem, causing internal stem necrosis, root rot and leaf shed. Moreover, the fungus is able to survive in soil for decades and its management is mainly preventive (Ploetz, 2006). Another serious threat for *Musa* is black sigatoka (black leaf streak), the most economically important banana leaf disease. It is caused by fungus *Mycosphaerella fijiensis* manifesting by significant defoliation and yield loss of the plant (Ploetz, 2006). Various fungi can cause crown rot of fruit, it appears at the tissue connecting banana fingers to each other called crown, and causes necrosis and rot. The disease symptoms usually occur during shipment, ripening, and storage (Lassois & Bellaire, 2014).

Another group of diseases is caused by nematodes, microscopic roundworms living as root parasites in soil. Major banana root pathogen is *Radopholus simils* (burrowing nematode), which has many other host plants including cultural crops beside banana and thus can spread easily through the agroecosystems. The adult nematode is only around 0.75 mm long which means it is invisible to the naked eye (Sipes et al., 2001). It causes lesions to roots and rhizomes, later resulting in toppling and yield loss (Ploetz, 2006). An infection caused by *Meloidogyne* spp., known as root-knot nematode, makes the roots swell, crack and rot. Necrosis of the root and corm tissues is then accelerated by other pathogens. Those nematodes are able to make the field unusable for banana production for up to five years (Ploetz, 2006).

Diseases connected with several yield loss are often caused by viruses, such as banana streak virus (BSV), banana bract mozaic virus (BBrMV) and especially banana bunchy top virus (BBTV). BBTV is spread by infected planting material or by its sole vector, banana aphid (*Pentalonia nigronervosa* Coquerel). Symptoms are dark green dots and streaks around the leaf midrib, later followed by leave shape deformation. Leaves become small, erect and bunched, with reduced internode distances on the pseudostem (Ploetz, 2006). Infected plants rarely produce a bunch and if they do, it is small and distorted (Ferreira et al., 1997).

2.3. Domestication

2.3.1. Origins

Modern banana cultivars have been developed through complex geodomestication pathways, including multiple intra and inter-specific hybridization events (Li et al., 2013). It happened in the Indo-Malesian region, and Malesia still keeps very high diversity of banana landraces, especially in Papua New Guinea (Kennedy, 2008). Bananas were mentioned already in the Ramayana, a Sanskrit epic originating in approximately 2,000 B.C. Alexander the Great described its cultivation in the lower Hindus Valley in India in the 327 B.C. Scriptures written during the Han dynasty (206 B.C. – 220 A.D.) in China mentioned it as well (Augustín & Valmayor, 2000). But the earliest archaeological evidence about domesticated *Musa* comes from Papua New Guinea and dates back more than 6,500 years (Denham et al., 2003).

Musa domestication history is very complex. First were used. various species growing in the Malesian region, mainly *M. acuminata*, *M. balbisiana* and their subspecies. At some point, people started to select plants with desired traits, propagate and grow them. Those plants were termed *"*cultiwild*"* by de Langhe et al. (2009). Every part of the plant is usable, either for food, fodder, medicine, shelter, fibre or ornamentals, including inflorescence, leaf, corm and seedy fruit. Kennedy (2009) suggested that other traits than seedlessness were important during the first stages of domestication, as Musaceae had been versatile plants already. DNA-markers study showed that subspecies of *M. acuminata* played major role in generation of numerous edible diploids and triploids (Carreel et al., 2000; Perrier et al., 2009).

Those parthenocarpic vegetatively propagated landraces spread west and mingled and hybridized with other *Musa* species, which produced new landraces (Perrier et al., 2009). Polyploidy appears as a consequence of meiotic restitution, when one diploid parent donates one genome copy and the other parent both (Cuenca et al., 2015). Two types of cultivars can occur, first, described above, are products of wild species and hybrids, and second are somatic mutants produced over long time-span during repeated clonal propagation. Beside the best known ancestors of vast majority of cultivars known today there are few others. *M. maclayi* F.Muell. ex Mikl.-Maclay contributed to development of the unique 'Fe´i' banana group in the Pacific, where they are indigenous (de Langhe et al., 2009). This group´s fruits are large, with yellow-orange pulp, rich in carotene precursors and bright red, orange or yellow peel. Fe´i plants can be distinguished by massive pseudostem, rather erected inflorescence and long maturation before producing fruits. Contribution to generation of edible varieties by *M. schizocarpa* Simmonds and *M. textilis* Née, whose genome is present in some tetraploid cultivars, is minor and probably recent (Langhe et al., 2009). Ancestor plants of modern banana cultivars (AA and BB genomes) are still cultivated, e.g. *M. balbisiana* in India, where its leaves serve as plates (Ambasta et al., 1986). It is also possible to find seedy fruits of unripe *M. balbisiana* in some markets in the Southeast Asia, as well as ripe fruits of *Ensete glaucum* (Roxb.) Cheesman, a musa-related species from another genus of the Musaceae family (Kennedy 2009). The genus *Ensete* is widely used in Asia and Africa, where is its homeland. Both *Musa* and *Ensete* have been grown in China for leaves as pig fodder since ancient times (Wu and Kress, 2000). *E. superbum* (Roxb.) Cheesman, native in India, has edible inflorescence similar to *Musa*, and the young seedy fruits can be pickled as well (Ambasta et al., 1986). *M. textilis* is still grown in the Philippines where it is a native species used for its fibre called abaca, which is extracted from its leaf sheats (FAO, 2017). For other miscellaneous uses of species belonging to the Musaceae family in the Indo-Malesian region, see Kennedy (2009).

2.3.2. Secondary domestication centre

The Central African Rainforest and the East African Highlands are considered the secondary domestication centre of bananas because many somatic mutants originated there. Bananas were introduced to Africa either via the Indian Ocean 2,000–3,000 years ago (De Langhe et al., 1994-5; de Langhe & De Maret 1999) or via Madagascar by people of Malaysian-Indonesian origin during the first millennium A.D. (Vansina 1990; Smartt & Simmonds 1995; Rossel 1998). Blench (2009), after considering the linguistic evidence, suggested that they were introduced there through the Western Africa together with other Indo-Pacific crops, such as taro [*Colocasia esculenta* (L.) Schott] or water yam (*Dioscorea alata* L.). This is widely accepted, but still lacking archaeological evidence. Nevertheless, both types of bananas were common and known at the West coast of Africa when the Portuguese arrived in the 15th century. Numerous distinct varieties could be found there, which points to long time cultivation and selection. There are approximately 120 AAB cooking-type cultivars originating in the rainforest in the Middle and the Western Africa, and around 100 AAA dessert-type cultivars from the Eastern African Highlands (De Langhe et al., 1994-5). The first ones, AAB, are known as plantains. Plantains are present in Malesia also but not of such diversity as in Africa. The highland bananas, commonly known as the East African Highland Bananas (EAHB), form a subgroup of the highest diversity in Africa. They are used for cooking, beer production and as dessert fruits (Lejju et al., 2006). Together with plantains, they form basis of food crop production in many parts of Africa (Swennen et al., 1995). Considering the *Ensete* genus in Africa, it is probably one of the oldest useful plants there. *E. ventricosum* (Welw.) Cheesman is still commonly planted in Ethiopia for its edible corm, a local traditional staple food (Yemataw et al., 2014).

Next region, sometimes highlighted as another centre of diversity is Southern India, located west from Malesia. It is typical with AAB triploids of Indian origin with numerous somatoclonal varieties and edible AB diploids which have only been recorded there (Fuller & Mandella, 2009).

2.3.3. Way to the New World

Later, bananas spread onward to the Mediterranean, and more substantially to the New World. First, the traders brought it from Guinea to the Canary Islands during the late 1400s. From there, bananas were introduced in today´s Dominican Republic in the 1500s. During the following centuries, more cultivars were introduced and spread throughout the Caribbean and Latin America by traders and settlers. Germplasms of cultivars 'Gros Michel' and 'Dwarf Cavendish', both with great breeding potential, were introduced from Southeast Asia in the 19th century (Marin et al., 1998). Langdon (1993) suggested that bananas were present in some areas of the New World even in the Pre-Columbian era, as they came with the voyaging Polynesians across the Pacific. Few common clones were found similar with the Pacific ones so there is possibility of an earlier introduction to the area. Nevertheless, there is no solid proof yet.

2.4. Study area

Peru is a coastal country in the Western South America (Figure 2.), washed by the South Pacific Ocean from the west, between Ecuador and Chile. It borders with Colombia, Brazil and Bolivia in the east (CIA, 2013). It is a democratic and political stable country since the 2000s, when a period of instability has been overcome. It can be classified as a middle-income country, however, with huge social and regional contrasts. The country compromises the ocean coast, which is the most densely populated area and vast rural areas in the Andes and the Amazon basin that are difficult to reach (The World Bank, 2006).

The Amazon basin is an extensive area divided between Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela. It is home to the world´s largest tropical forest and retains wide diversity of plants and animals. It is estimated to be inhabited by more than 30,000 species of vascular plants (Silman, 2011). Some of those are agricultural crops with long cultivation history. During the European conquest, there were described 83 crop species native to Amazonia with some degree of domestication (Clement, 1999). Numbers of wild edible plants and medicinal plants remain unknown. Mittermeier et al. (1997) ranked Brazil, Colombia, Ecuador, Peru and Venezuela among the 17 biodiversity-richest countries of the world, with particular focus on endemic biodiversity. Some parts of the Peruvian Amazon hold the world records for diversity of mammal, bird, reptile, butterfly, orchid and woody plant species (Gentry, 1988). Area drained by the Amazon River and its tributaries covers approximately 7,500,000 km^2 (Goulding et al., 2003). The basin stretches on 760,000 km^2 of the Peruvian territory, which makes up around 60 % of the country´s total area (IIAP, 2017).

Figure 2. Study area - Peru

Study area of this work is Pucallpa, a city lying in the northern part of the Ucayali region. Ucayali, the second largest of Peru´s administrative regions, covers an area of 102 thousand km^2 (INEI, 2011). Biotope of this area is predominantly tropical lowland forest as it climbs up the slopes of Andes only at the southern and the western borders with other regions. The main river of the region is the Ucayali, which forms the Amazon River after confluence with the Marañón River near Iquitos. More than 60 % of the Ucayali's inhabitants lived in the capital Pucallpa by the year 2011 (INEI, 2012).

Pucallpa's was estimated to have population of 211,000 in the year 2015, with distinct ethnical groups from both the Amazon and from other parts of the country. Those are mainly Shipibo-Conibo natives of the Amazon and Mestizos, who have partially European ancestors (INEI, 2012). Pucallpa, the second most populated city in the Peruvian Amazon, is local economical centre because of its road connectivity to Lima and boat connection to Iquitos, the largest city in the Peruvian Amazon. It was chosen as our study area because most of the region´s products go first to Pucallpa before further reselling and therefore it can be place providing sources of valuable data.

Pucallpa dates back to an early colonial era but it had not been accessible until the 846 km long road from Lima was built during the 1940s. Since that, it has become a centre for logging, forest exploitation and agriculture production, its position on the bank of the Ucayali River making it even easier and more profitable. There is also an oil refinery since the 1966 but logging remains the major industry together with agriculture (Ramos-Delgado, 2008).

The most common crops are staples, e.g. maize (*Zea mays* L.), cassava (*Manihot esculenta* Crantz), rice (*Oryza sativa* L.), plantains or beans (*Phaseolus* spp.); cash crops, e.g. cocoa (*Theobroma cacao* L.), coffee (*Coffea arabica* L.), and oil palm (*Elaeis guineensis* Jacq.); and various fruit species, e.g. papaya (*Carica papaya* L.), aguaje (Mauritia flexuosa L.f.), camu-camu [Myrciaria dubia (Kunth) McVaugh], annonna (*Annona* sp.) or dessert bananas. Local importance of bananas and plantains can be seen while entering Pucallpa, statue of farmer, "el chacarero" (chacra = small farm), is standing right on the main road. It seems like he is just returning from harvest, notice the bunch of plantains on his back (Figure 3.). Other cash crop, not mentioned officially, is coca (*Erythroxylum coca* Lam.). Though the specific environmental conditions for growing coca are more suitable in the tropical Andes, it has been spread into the Amazon basin also (Dillenhay et al., 2010). The most common agriculture system and management of crops is based on traditional short-fallow swiddens with progressive clearing and burning of forest or old fallows (Labarta et al., 2008). Amplified by growing population, slash-and-burn farming is the major driver of forest loss in the Peruvian Amazon (Alvarez & Naughton-Treves, 2003).

Figure 3. "El chacarero" with plantains

3. Aims of the Thesis

Based on scarce literature sources about bananas in Amazonia, which indicated their great diversity in the Ucayali region, following research question was formulated: What are particular cultivars´ specifics, use patterns and importance among locals in the Ucayali region?

To answer this, we set following objectives:

a) To determine diversity of banana cultivars commercialized in Pucallpa markets, including their morphological characterization.
b) To document knowledge about their uses.
c) To describe their sensory characteristics and consumers´ overall acceptance.

4. Materials and Methods

4.1. Market survey

Brief inventory of markets was done as a first step, regarding the advices of Martin (2004) on market surveys. Pucallpa has seven main retail markets (Minorista, Bellavista, Yarinacocha, One, Two, Three and Four) (See Figure 4. and 5.). Bellavista used to be the main one until Minorista was built and filled with vendors during the last few years. After the inventory, Minorista market appeared ideal for this investigation. It is the biggest and the most popular market in Pucallpa despite being far from the city centre. Its area was unofficially enlarged by numerous shops opened around it in the closest buildings and halls, creating all together huge area full of shops. However, the offer does not differ so much between vendors as it depends mostly on what is shipped that morning to the city by boats and trucks. Vendors buying also from smaller sources and farmers can have more rare products but only once in a while.

Figure 4. Market Minorista

Figure 5. Market Three

4.2. Sample preparation

Samples for all parts of the research were bought in early mornings shortly after vendors opened. Fruit hands were wrapped in newspapers, packed in paper boxes and transported to one of the two local universities, Universidad Nacional de Ucayali (UNU) and Universidad Nacional Intercultural de la Amazonía (UNIA), for further evaluations.

4.3. Morphological characterization

4.3.1. Photodocumentation

Samples of all cultivars were photodocumented using Olympus TG-30 digital camera. First, hand of each cultivar was placed in the middle of white A2 paper, using 15 cm long ruler as a scale. Second, composition was made of one whole fruit finger, longitudinal section of finger with peel, cross section of finger with peel and the ruler.

4.3.2. Descriptors

All the varieties were described by previously published descriptors by International Plant Genetic Resources Institute (IPGRI) & International Network for the Improvement of Banana and Plantain (INIBAP) (1996).

Used descriptors were: Number of fruits in one hand (observed on the mid-hand of the bunch), fruit length (in cm, measured as the internal arc of the fruit, without pedicel), fruit shape (longitudinal curvature) (Figure 6.), transverse section of fruits (observed on mature fruit) (Figure 7.), fruit apex (observed at the distal end of the fruit) (Figure 8.), remains of flower relicts at fruit apex (observed at the distal end of the fruit) (Figure 9.), fruit pedicel length [mm], fruit pedicel width [mm], fusion of pedicels, mature fruit peel colour (at full yellow stage of maturity), fruit peel thickness [mm] and pulp colour at maturity (at full yellow stage of maturity).

In case of number of fruits in one hand, an average bunch of bananas was chosen on market, inspected for the number of fruits in each hand.

In cases of characteristics fruit length, fruit pedicel length and fruit pedicel width, they were observed on three average fruits from three hands. Then, averages were made.

Fruit shape, transverse section of fruits, fruit apex, remains of flower relicts at fruit apex, fusion of pedicels, mature fruit peel colour and fruit peel thickness [mm] were observed on fingers of three average hands.

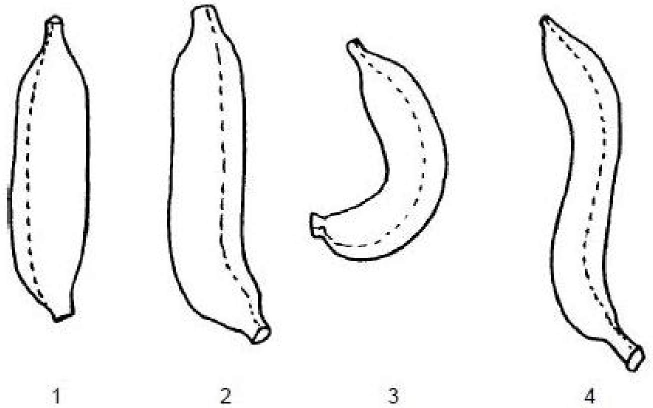

Figure 6. Fruit shape (longitudinal curvature): 1 - Straight (or slightly curved), 2 - Straight in the distal part, 3 - Curved (sharp curve), 4 - Curved in ‘S’ shape (double curvature)
(adapted from Dodds and Simmonds, 1948)

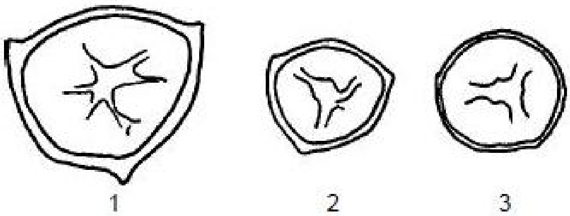

Figure 7. Transverse section of fruit: 1- Pronounced ridges, 2 - Slightly ridged, 3 - Rounded
(adapted from Dodds and Simmonds, 1948)

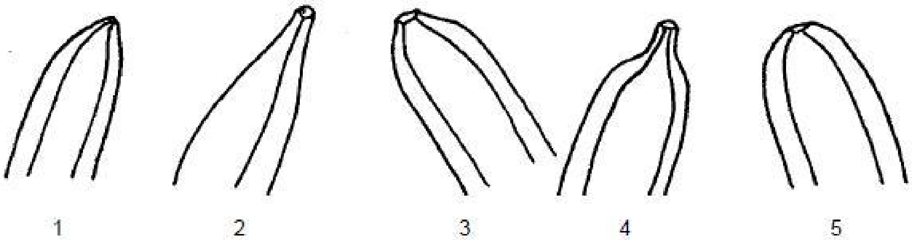

Figure 8. Fruit apex: 1- Pointed, 2 - Lengthily pointed, 3 - Blunt-tipped, 4 - Bottle-necked, 5 - Rounded
(adapted from Champion, 1967)

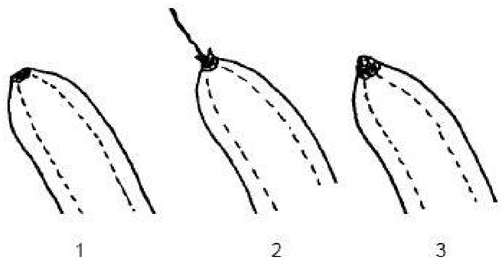

Figure 9. Remains of flower relicts at fruit apex: 1 - Without any floral relicts, 2 - Persistent style, 3 - Base of the style prominent (adapted from IPGRI & INIBAP, 1996)

4.3.3. Weight and pulp to peel ratio

Weight of ripe fruits was measured afterwards, specifically weight of whole fruit, pulp and peel. Three average fingers were chosen for measuring purposes, each from one hand. It was performed on scale ADAM CB1001. The values were used for calculating pulp to peel ratio according to the following formula (Tapre & Jain, 2012):

$$\text{Peel to pulp ratio} = \frac{\text{Weight of fruit pulp}}{\text{Weight of fruit peel}}$$

4.4. Sensory evaluation

4.4.1. Degustation panel

Ripe banana hands from six dessert cultivars were used for evaluation in degustation panel. The cultivars were 'Capirona', 'Isla', 'Manzano', 'Muqicho', 'Rojo' and 'Seda'. They are used primarily for direct raw consumption or in non-alcoholic beverages preparations. Banana fingers were separated from the hands and peeled. The pulps were cut in one cm thick slices and placed in plastic closable box. Each pulp sample was accompanied by random three-digit code (Lawless & Heymann, 2010). Evaluation set consisted of the plastic box with six pulp samples put in there with no order. Panellists were also given a plastic fork and supplied with palate cleansers, water and table water crackers, in order to use them between evaluating each sample (Lucak & Delwiche, 2009).

The degustation panel was set up in the campus of UNIA. Twenty-six students of the university were employed as untrained panellists. They were between 20 and 26 years old. All of them were regular banana consumers and costumers of the Minorista market. The group was represented by 18 men and 8 women.

4.4.2. Evaluation sheet

Evaluation sheet was designed to take no more than 15-20 minutes, which is the approximate attention span of adults (Schaefer & Wax, 1979). Panellists were asked to evaluate the cultivars´ taste, texture and acceptance, using hedonic scales, by sweetness, acidity, stickiness, toughness, juiciness and overall acceptance.

Taste evaluation of samples´ sweetness and acidity was done drawn 5-point scale with described points (e.g. not sweet, slightly sweet, medium-sweet, very sweet and extremely sweet) (Peryam & Girardot, 1952).

For texture evaluation was chosen stickiness for adhesiveness, toughness for cohesiveness (Szczesniak et al., 1963) and juiciness. The drawn scale was the same as in the taste evaluation.

Overall acceptance was evaluated on the 9-point hedonic scale (Peryam & Girardot, 1952), with points described as: Like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely.

4.5. Local knowledge assessment

4.5.1. Participants

Knowledge of banana cultivars´ was investigated on 35 respondents: 27 university students and 8 market vendors. University students were from 20 to 26 years, 8 women and 19 men. Market vendors were from 31 to 60 years, 6 women and 2 men.

4.5.2. Plant interview

In the case of students, plant interview (Alexiades, 1996) on cultivars´ ethnobotanical knowledge was performed inside their facility in UNIA. In the case of vendors, this was done straight in the market using printed materials. Both groups were shown pictures of banana varieties without description, in ripe and unripe stage. Their tasks were to fill in prepared sheet, which questioned cultivars´ names and uses.

Names were free listed, for results were used names with at least two records. For uses, there were named basic specific uses of bananas to mark, moreover, participants were allowed to free list other uses. Specific uses to mark were: direct, fruit salad, juice, chapo (thermally prepared beverage), cooked, roasted, fried, flour, chifles (banana chips) and medicinal. The marking box for medicinal use was accompanied by two more specifying characteristics, free listing for use and parts used, again at least two records were required.

Later, the specific uses were later categorized in "Preparation types" in order to perform data analyis. The categories, starch based preparations, sweet dishes, fresh, non-alcoholic beverages and other preparations, were based on Level Three classification of Economic botany data standard (Cook, 1995).

4.6. Data analysis

Data sheets for analysis were prepared using Microsoft Excel 2010. The Excel was used for preparing pivot tables with consumers´ knowledge about cultivar names and uses also. STATISTICA 12 was used for data analysis of the sensory evaluation and overall acceptace. One-way ANOVA and Tukey´s honest significance test were performed in order to obtain means and their significant differences. Moreover, correlation coefficients on the significance level ($P < 0.05$) were calculated. They were interpreted according to rule of (Hinkle et al., 2003). It was also necessary to interpret them with opposite plus and minus signs as the scales for taste and texture evaluation were oriented in opposite direction to the overall acceptance scale.

5. Results

5.1. Morphological characteristics

Eleven banana cultivars were described in the Minorista market in Pucallpa: 'Bellaco', 'Campeón', 'Capirona', 'Común', 'Isla', 'Mamaluca', 'Manzano', 'Muquicho', 'Rojo', 'Sapucho' and 'Seda' (Figure. 10.). Cultivars ´ morphological characteristics were listed in Table 2. For more photos, see Appendix: Sections of the cultivars investigated.

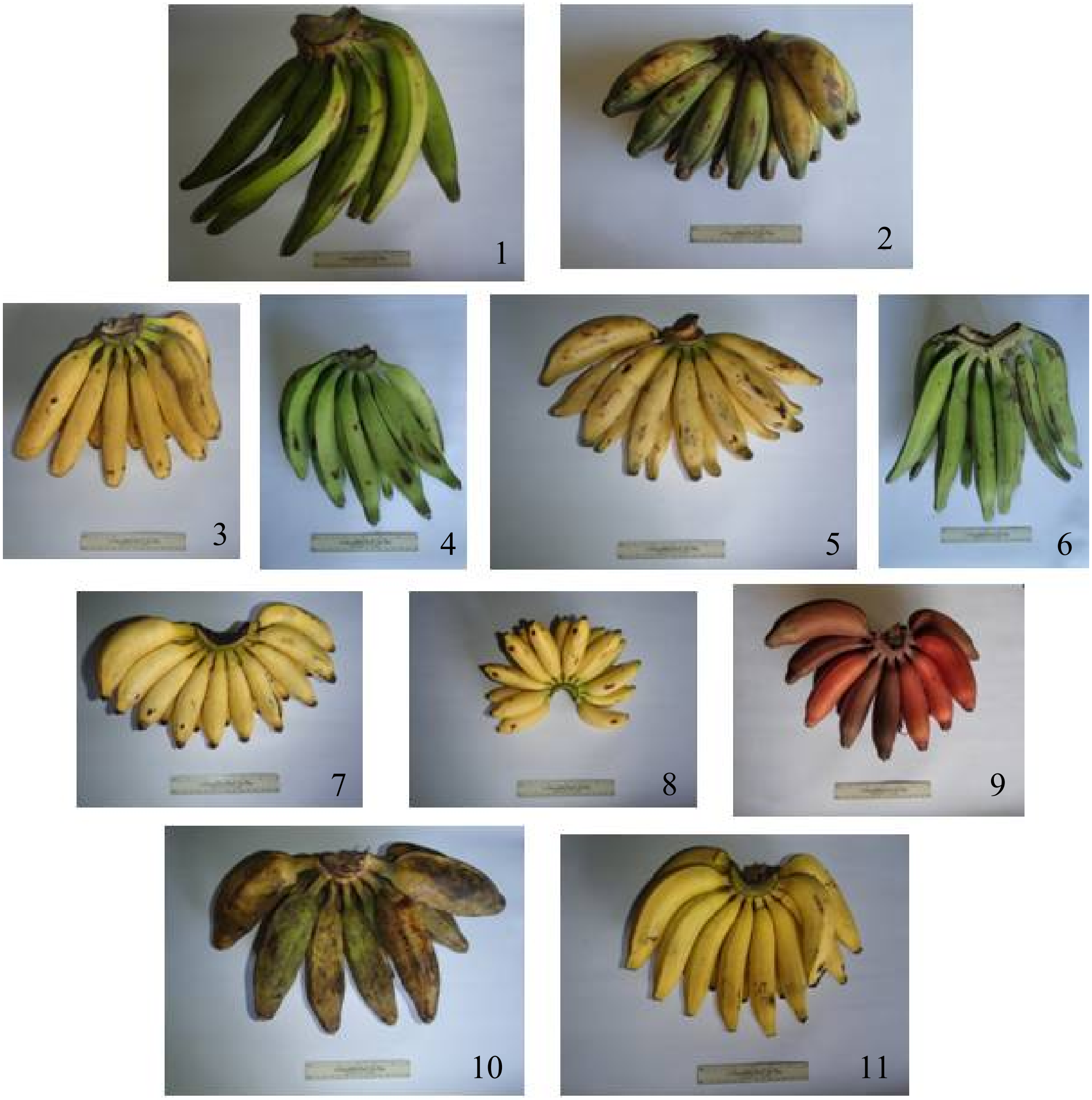

Figure 10. Hands of local cultivars: 1 - 'Bellaco', 2 - 'Campeón', 3 - 'Capirona', 4 - 'Común', 5 - 'Isla', 6 - 'Mamaluca', 7 - 'Manzano', 8 - 'Muquicho', 9 - 'Rojo', 10 - 'Sapucho', 11 - 'Seda'

Table 2. Morphological characteristics

Descriptors	Cultivars					
	'Bellaco'	'Campeón'	'Capirona'	'Común'	'Isla'	'Mamaluca'
Number of fruits in one hand	≤12	13–16	≤12	≥17	≤12	13–16/≥17
Fruit length	21–30 cm	≤15 cm	16 –20 cm	16–25 cm	≤15 cm/16–20 cm	21–25 cm
Fruit shape	Straight in the distal part	Straight (or slightly curved)	Straight in the distal part	Straight in the distal part	Straight (or slightly curved)	Curved in 'S' shape (double curvature)
Transverse section of fruits	Pronounced ridges	Pronounced ridges	Pronounced ridges / Slightly ridged	Pronounced ridges	Slightly ridged	Pronounced ridges
Fruit apex	Lengthily pointed	Pointed / Bottle-necked	Blunt tipped / Rounded	Lengthily pointed	Bottle-necked / Lengthily pointed	Lengthily pointed
Pedicel surface	Hairyless	Hairyless	Hairyless	Hairyless	Hairyless	Hairyless
Fusion of pedicels	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion
Mature fruit peel colour	Yellow	Yellow	Yellow / Bright yellow	Yellow	Yellow / Pale yellow	Yellow
Fruit peel thickness	>2 mm	>2 mm	≤2 mm	>2 mm	>2 mm	>2 mm
Pulp colour at maturity	Cream/Yellow/Orange	Yellow	Cream/Yellow/Orange	Yellow/Orange	Ivory/Orange	Yellow/Orange

Descriptors	Cultivars				
	'Manzano'	'Muquicho'	'Rojo'	'Sapucho'	'Seda'
Number of fruits in one hand	13–16	≥17	13–16	13–16	13–16/≥17
Fruit length	≤15 cm	≤15 cm	≤15 cm	≤15 cm / 16–20 cm	≤15 cm
Fruit shape	Straight (or slightly curved) / Curved (sharp curve)	Straight (or slightly curved) / Curved (sharp curve)	Straight (or slightly curved) / Straight in the distal part	Straight (or slightly curved)	Straight (or slightly curved) / Straight in the distal part
Transverse section of fruits	Rounded / Slightly ridged	Rounded	Rounded	Pronounced ridges	Slightly ridged
Fruit apex	Bottle-necked	Pointed	Blunt-tipped/ Bottle-necked	Pointed	Pointed / Blunt tipped
Pedicel surface	Hairyless	Hairyless	Hairyless	Hairyless	Hairyless
Fusion of pedicels	Partially fused	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion	Very partially or no visible sign of fusion
Mature fruit peel colour	Yellow / Pale yellow, often with grey spots	Yellow	Red	Yellow / Brown or rusty-brown	Yellow
Fruit peel thickness	≤2 mm	≤2 mm	>2 mm	>2 mm	≤2 mm
Pulp colour at maturity	Yellow/Cream	Yellow/Orange	Cream/Yellow/Orange	Yellow/White	Yellow

Weight and pulp to peel ratio were measured in the local cultivars. Among them, the highest mean ripe fruit weight was observed in plantain cultivar 'Bellaco', it was at least one time heavier than all the other cultivars. Second, with similar weight were cooking-type cultivars 'Mamaluca' and 'Sapucho'. On the other hand dessert-type cultvars 'Muquicho', 'Manzano' and 'Seda' were the lightest (Figure 11.). The pulp to peel ratio in our study ranged from 1.38 in 'Mamaluca' to 3.02 in 'Muquicho'. The highest mean pulp to peel ratio was found in the three dessert cultivars: 'Muquicho', 'Manzano' and 'Seda'. On the other hand, cooking-type cultivars 'Mamaluca', 'Sapucho' and 'Común' performed the lowest pulp to peel ratio (Figure 12.).

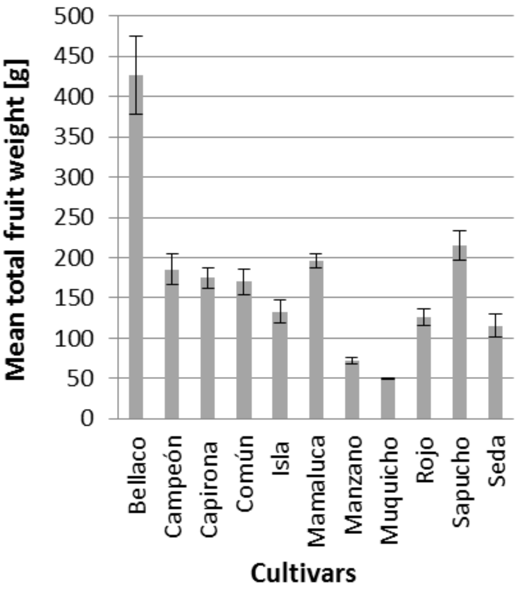

Figure 11. Mean total fruit weight

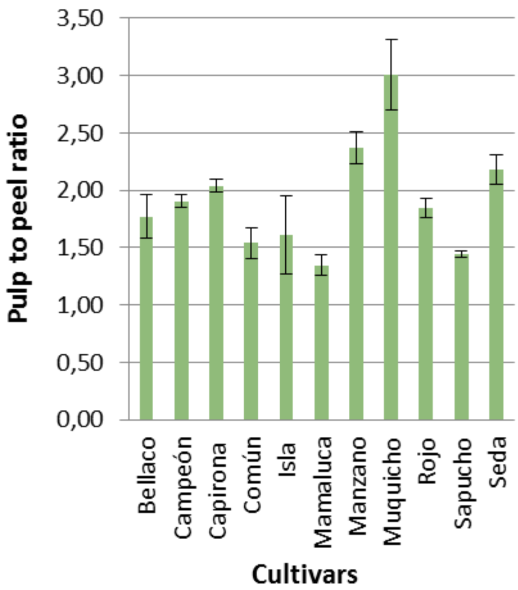

Figure 12. Mean pulp to peel ratio

5.2. Sensory evaluation

Among six dessert cultivars, consumers evaluated 'Seda', 'Muquicho' and 'Rojo' as the sweetest, and 'Manzano', 'Isla' and 'Capirona' as the most acid. As the stickiest were evaluated 'Manzano', 'Rojo' and 'Capirona', as the toughest 'Isla', 'Capirona' and 'Manzano', and as the juiciest 'Muquicho', 'Rojo' and 'Seda'. The highest overall acceptance was ranked in cultivars 'Seda', 'Muquicho' and 'Manzano' (Table 3.). Overall acceptance of 'Seda' was significantly different from rest of the cultivars.

Table 3. Sensorial properties and overall acceptance of local cultivars

Characteristics	Cultivars											
	Capirona		Isla		Manzano		Muquicho		Rojo		Seda	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sweetness	1.92 [a]	0.63	2.08 [a]	0.63	2.96 [b]	0.77	2.96 [c]	0.85	3.42 [bc]	1.06	4.04 [c]	0.92
Acidity	1.38 [a]	0.57	2.04 [b]	0.77	2.65 [c]	1.02	1.12 [a]	0.33	1.27 [a]	0.53	1.08 [a]	0.27
Stickiness	2.27 [a]	1.00	2.19 [a]	1.27	2.85 [b]	1.12	2.00 [ac]	1.02	2.50 [abc]	1.03	1.65 [ad]	0.80
Toughness	2.50 [a]	1.17	3.00 [a]	1.06	2.42 [a]	1.03	1.38 [b]	0.70	1.54 [b]	0.81	1.35 [b]	0.69
Juiciness	3.08 [ad]	1.13	2.00 [b]	1.17	2.81 [b]	0.75	3.65 [ab]	0.85	3.58 [ab]	0.95	3.42 [d]	0.99
Overall acceptance	4.81 [a]	1.55	4.69 [a]	1.74	2.81 [b]	1.33	2.38 [b]	1.27	3.54 [b]	1.82	2.04	1,11

SD – standard deviation
Means not sharing the same superscript within a row are significantly different ($P < 0.05$).

On the significance level ($P < 0.05$), there was low positive correlation between sweetness and overall acceptance in cultivars 'Manzano', 'Muquicho', 'Rojo' and 'Seda', high and moderate negative correlation between acidity and overall acceptance of 'Seda' and 'Muquicho', low negative correlation between toughness and the acceptance of 'Rojo', and low positive correlation between juiciness and the acceptance of 'Manzano' and 'Seda' (Table 4).

Table 4. Correlations between sensory characteristics and overall acceptance

Characteristics	Cultivars					
	Capirona	Isla	Manzano	Muquicho	Rojo	Seda
Sweetness	0.34	0.23	0.44*	0.45*	0.41*	0.39*
Acidity	-0.22	-0.07	0.17	-0.76*	-0.38	-0.65*
Stickiness	-0.37	-0.10	-0.01	0.06	-0.06	0.25
Toughness	-0.19	0.17	-0.30	0.04	-0.39*	0.17
Juiciness	0.36	0.00	0.40*	0.17	0.14	0.42*

* - Correlation coefficients on the significance level ($P < 0.05$)

5.3. Local names

Most of the cultivars were reported to have at least one or more local names. The highest number of names was reported in Muquicho. On the other hand, there has not been found any synonym for 'Bellaco', 'Campeón' and 'Isla'. 'Campeón' itself was recorded under this name for the first time according to our best knowledge. 'Uva', a synonym of 'Rojo', was recorded also for the first time. See Table 5, where is the list of cultivars and their synonyms and classification presented. It was completed according to Krauss (1999).

Table 5. Local names, synonyms, and classification of cultivars investigated

Cultivar	Local names	Other synonyms in Peru (Krauss, 1999)	International classification (group; subgroup; cultivar) (Krauss, 1999)
'Bellaco'		Barraganete, Cuerno, Hartón, Macho	AAB group; plantain subgroup; 'Hartón'
'Campeón'			
'Capirona'	Guyabo, Palillo	Canela, Guayaquil, Maqueño, Rey, Vaporino	AAB group; Maia Maoli subgroup; ('Ecuadorian Maqueño')
'Común'	Inguiri	Asapa Plátano, Arcanchaco, Común, Delgado, Dominico, Largo, Hembra, Paisano, Plátano Bueno, Plátano de Freir, Sancochado	AAB group; plantain subgroup; 'Green French Plantain'
'Isla'		Cuadrado, Manzano	
'Mamaluca'	Común mamaluca	Mameluco, Bellaco Cachaco	AAB group; plantain subgroup; 'Plantain'
'Manzano'	Manzanilla	Apple, Guineo Manzano, Mansanita, Maca	AAB group; silk subgroup; 'Manzano'
'Muquicho'	Muquichi, Muquichico, Moquicho, Guineo, Biscocho	Azucarado, Bocadillo, Canelita, Ciento en Boca, Datíl, Guineo Mequiche, Lady's Finger, Limenillo, Orito, Oro, Ouro, Perita, Platanito de Oro	AA group; 'Sucrier'

'Rojo'	Uva	Morado, Guineo, Guineo Rojo, Indio, Morado Oscuro	AAA group; Red subgroup; 'Red'
'Sapucho'	Sapo	Balsino, Burro, Chato, Cuadrado, Huaybino, Sapino, Sapote	ABB group; Bluggoe subgroup; 'Bluggoe'
'Seda'	Ceda, Guineo		AAA group; Gros Michel subgroup; 'Gros Michel'

5.4. Cultivars´ uses

“Starch based preparations” were the category with the highest total number of records, cooking-type cultivars 'Común', 'Bellaco' and 'Mamaluca' had the highest number of records. In the preparation type “Fresh”, 'Seda', 'Manzano', 'Muquicho', all dessert-types, had the highest numbers of records. “Sweet dishes” preparation types were recorded the least time, 'Seda' and 'Bellaco' had the highest number of records. “Non-alcoholic beverages” were reported in both cultivar types, but 'Capirona', 'Seda' and 'Muquicho' were the most common. Use category “Other” was most commonly mentioned with connection to 'Bellaco', 'Común' and 'Mamaluca'. See Figure 13., where are the preparation type categories presented in graph.

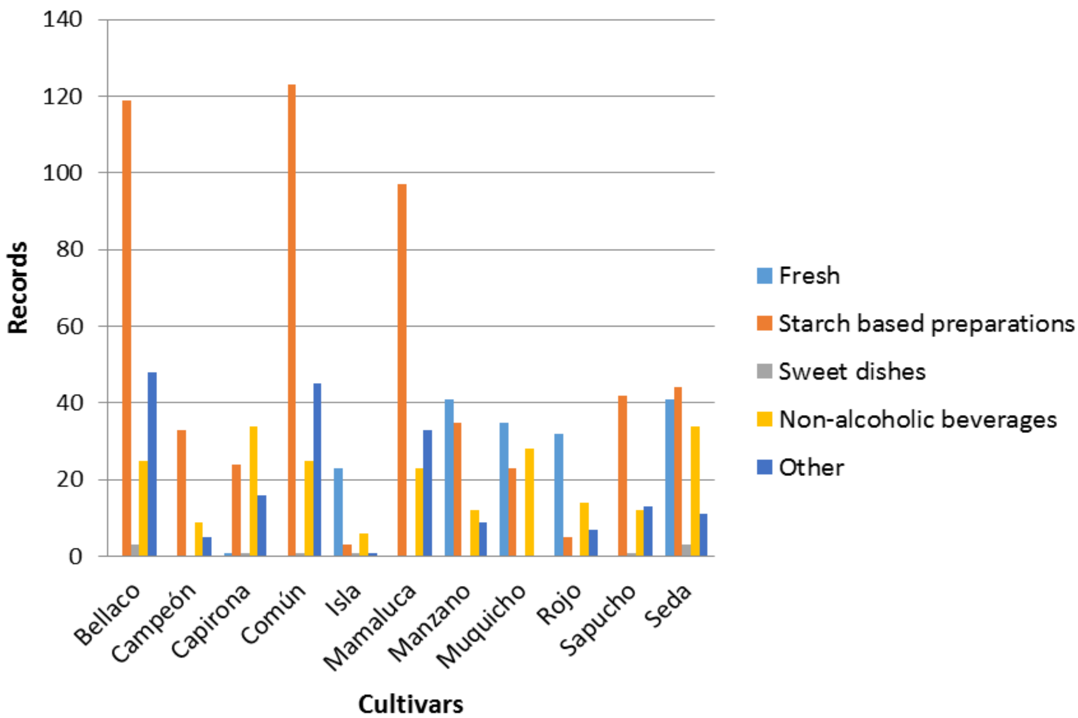

Figure 13. Preparation type categories

Four specific uses except the given possibilities, described in the chapter Materials and Methods, appeared (mazamorra – a pudding-like dessert, purée, stewed and tacacho – a breakfast dish from mashed cooking banana and fried pork fat).

The most reported were “Starch based preparations”, some of the investigated cultivars can be cooked, fried, roasted, stewed, or used for tacacho. Plantains 'Común', 'Bellaco' and 'Mamaluca' had the highest number of records as cooked, fried and roasted. Moreover, 'Bellaco' was the most reported cultivar for preparation of tacacho. In the preparation type “Fresh”, there were recorded specific uses as snack and fruit salad. 'Seda' had the highest numbers of records in both uses. Mazamorra, prepared from unripe 'Bellaco', 'Común' or 'Seda', and purée, which was reported to be made from 'Capirona', 'Isla' and 'Sapucho', were the only “Sweet dishes” described by the informants. Many cultivars, both dessert and cooking-type, are reportedly used for preparations of “Non-alcoholic beverages” but the dessert-type cultivars predominated. Chapo was reported to be made mainly from 'Capirona', and juice from 'Seda' and 'Muquicho'. In the last preparation types category “Other” were reported several cultivars used for making flour and chifles. However, for the both uses were most commonly mentioned the plantains 'Bellaco', 'Común' and 'Mamaluca'.

Moreover, 'Común', 'Rojo', 'Sapucho' and 'Seda' were reported to be used as medicine. However, respondents were mostly not able to give any detailed information about conditions of uses or preparations. 'Común' was reported to be used against stomach problems in both unripe and ripe stages and against tuberculosis and diabetes in unripe stage. In cultivar 'Rojo', respondents were able to describe one medicinal use in detail: Pseudostem is cut off and a hole scooped out in the cut surface. Until the next day, the hole is filled with plant´s liquid. That is then consumed orally against gastritis. It is done usually after harvest because it requires killing the plant. Moreover, fruit of 'Rojo' was reported to have unknown medicinal uses in both, unripe and ripe stages. 'Sapucho' was reported to be used unripe against diabetes and ripe against gastritis. 'Seda' was reported to have unknown medicinal use in unripe stage. Moreover, peel of ripe 'Seda' can be applied on face against wrinkles. See following Table 6, which summarizes the knowledge about use of local cultivars in different stages of ripeness.

Table 6. Summary of knowledge about local banana cultivars

Cultivar		Preparation types and specific uses				
	Ripe stage	Fresh	Starch-based preparations	Sweet dishes	Non-alcoholic beverages	Others
'Bellaco'	Unripe		Cooked, fried, roasted, tacacho	Mazamorra		Flour, chifles
	Ripe		Cooked, fried, roasted, tacacho		Chapo, juice	Flour, chifles
'Campeón'	Unripe		Cooked, fried, roasted			Chifles
	Ripe		Cooked, fried, roasted		Chapo	Chifles
'Capirona'	Unripe		Cooked, fried, roasted			Flour, chifles
	Ripe		Fried, roasted	Purée	Chapo, juice	Chifles
'Común'	Unripe		Cooked, fried, roasted	Mazamorra		Flour, chifles, medicinal
	Ripe		Cooked, fried, roasted		Chapo	Flour, chifles, medicinal
'Isla'	Unripe					
	Ripe	Snack, fruit salad		Purée	Chapo, juice	
'Mamaluca'	Unripe		Cooked, fried, roasted			Flour, chifles
	Ripe		Cooked, fried, roasted		Chapo, juice	Flour, chifles

'Manzano'	Unripe		Cooked, fried, roasted			Flour, chifles
	Ripe	Snack, fruit salad			Juice	
'Muquicho'	Unripe		Cooked, fried, roasted, stewed			
	Ripe	Snack, fruit salad	Roasted		Chapo, juice	
'Rojo'	Unripe		Fried			Flour, medicinal
	Ripe	Snack, fruit salad	Roasted		Chapo, juice	Medicinal
'Sapucho'	Unripe		Cooked, fried			Chifles
	Ripe		Cooked, fried, roasted, stewed	Purée	Chapo	Chifles, medicinal
'Seda'	Unripe		Cooked, fried, roasted	Mazamorra		Flour, medicinal
	Ripe	Snack, fruit salad	Cooked, fried, roasted		Chapo, juice	

6. Discussion

6.1. Morphological characteristics

Morphological characteristics of cultivars found in Pucallpa generally corresponded with their genomic groups. The dessert-type cultivars were mostly characterized by a higher number of fruits in one hand, smaller size of one fruit, thinner peel and rounded or only slightly ridged shape of transversal fruit section, compared to cooking-type cultivars, which corresponded with Gibert et al. (2009) and Hapsari and Lestari (2016). It reflects growth habit and fruit formation of respective genomic groups. 'Rojo' and 'Isla' surpassed other dessert cultivars in peel thickness. In this regard, thick peel is typical for the Red subgroup cultivars (Kepler & Rust, 2011). Morphological characterization of plantains, cooking and dessert banana cultivars was performed by Gibert et al. (2009). In his study, the largest fruits were found in plantains. It corresponded with our case, all the plantain cultivars 'Bellaco', 'Común' and 'Mamaluca', had fruit length at least 16 cm. Also corresponding with our findings, Gibert et al. (2009) found the cooking-types except of plantains to be of similar fruit size like the dessert-type cultivars.

Fruit apex and fruit shape varied greatly among the cultivars and did not correspond to their genomic groups as much as the above-mentioned characteristics. However fruit apex was pointed or lengthily pointed in all cooking-type cultivars, which is typical especially for plantains. Fruit shape was straight (or slightly curved) in most of the cases, while some of them had more possibilities of the fruit shape. Banana fruit shape may differ in one cultivar, as banana possesses great intra-cultivar variability, often reflected in fruit shape (Kitavi, 2015). For example, Krauss et al. (1999) demonstrated variability of 'Isla' by showing characteristics of five distinct clones, each of them with little bit different shape. This is due to somatical mutations, which develop during long time cultivation under certain conditions (Pushkaran et al., 1990).

Colour of banana fruit depends on the pigments present. When green chlorophyll in peel degrades, it unmasks the colours of carotenoid and eventually anthocyanin pigments (Matile et al. 1999). Observed cultivars possessed different mature peel colours, mostly various tones of yellow, 'Rojo' being the only red cultivar. Mature peel colour reflects carotenoid content in peel (Subagio et al., 1996) and in pulp possibly also. The red-coloured cultivar 'Hongjiaowang' in the study of Xiumin et al. (2017) contained a higher total amount of carotenoids in both peel and pulp than other cultivar with yellow peel. There have been a few studies evaluating banana peel nutrient content, and finding it a good potential source of dietary food components for human nutrition, such as fibres, minerals or carbohydrates (Emaga et al. 2007; Mohapatra et al. 2010). Though it is possible to eat the peel of some dessert-type cultivars, it is not usually practised by humans, for whom the pulp is much more important because of its palatability.

Colour of mature pulp reflects also the presence of carotenoids, the cultivars 'Isla', 'Mamaluca', 'Muquicho', 'Rojo', and 'Seda' appeared to be closest to the bright yellow-orange colour, which could indicate higher provitamin A level in their fruit compared to more pale-coloured cultivars. Though it is possible to estimate which cultivars could be potential source of provitamin A based on human eye observation, more advanced methods of colour assessment are recommended. The intake of provitamin A, antioxidant, which has a crucial effect on functioning of human immunity and maintains healthy vision and skin, is important especially during pregnancy. Its sufficient intake is still an issue in Peru, where the rates of provitamin A deficiency are among the highest in South America (Lechtig et al., 2009).

A few previously published studies (Englberger et al., 2006; Wall, 2006) assessed vitamin contents in cultivars investigated in our study. Previous analysis of Micronesian cultivars found 315 μg of β-carotene in 'Sucrier' ('Muquicho') and 417 μg of β-carotene/100 g in 'Red' ('Rojo') (Englberger et al., 2006). It shows that some local cultivars are rich in provitamin A carotenoids, and may offer a potential food source to alleviate vitamin A deficiency in tropical countries like Peru.

On the other hand, cultivars with rather pale pulp are poorer sources of carotenoids. Wall (2006) showed that 'Dwarf Brazilian' ('Manzano') contained only 12.4 μg/100 g of provitamin A carotenoids. 'Manzano' is known for its sour-sweet taste however it is not the very good source of ascorbic acid. Its mean vitamin C content was only 12.7 mg/100 g, and in some clones little over 17 mg/100g Wall (2006), which makes it a worse source of vitamin C in comparison to locally available fruits of papaya, camu-camu and citruses.

In mean fruit weight, the cultivars of plantains ('Bellaco', 'Mameluca'), and cooking bananas ('Sapucho'), scored with the highest mean weight. In the study of Dufour et al., (2008), 'Hartón' had one of the highest mean fruit weights (396 g) among tested cultivars. 'Hartón' is synonyme of' 'Bellaco', which scored similar average weight of 402 g in our study. Compared to morphology of other cooking bananas, 'Bellaco' is among the heaviest ones (Swennen & Vuylsteke, 1996; Dufour et al., 2008; Selatsa et al., 2009). Lighter 'Seda' with 116 grams also roughly corresponded to 'Gros Michel' with 133 grams (Dufour et al., 2008). However, it is not sure if those banana cultivars were identical with the ones found in Pucallpa despite being identified as synonyms.

According to Anhwange et al. (2008), banana peel constitutes about 40 % of total weight of the ripe fruit, that means pulp to peel ratio is about 1.5. This would correspond with Belayneh (2014), who found the ratio in cooking cultivars between 1.2 and 1.9. In our study, it ranged between 1.38 and 3.02 because of distinct cultivars of both cooking and dessert-types. In compliance with Newilah et al. (2009), we found the highest pulp to peel ratio in the dessert-type cultivars 'Muquicho', 'Manzano' and 'Seda'. Cultivars´ pulp to peel ratio in his study ranged between 2.2 and 3.7 in cooking-type and between 2.4 and 4.7 in dessert-type cultivars in most of his studied cultivars. Mohapatra et al. (2016) investigated one cultivar of Red subgroup, finding its pulp to peel ratio 2.6 in the last stage of ripening. Therefore it seems this particular cultivar is distinct from 'Rojo' investigated in our study, as it scored only 1.85.

6.2. Sensory evaluation

It is not surprising that the popular and very sweet cultivars 'Seda', 'Muquicho' and 'Manzano' performed the highest overall acceptance among the other dessert-type cultivars. It corresponds with findings of Ekesa et al., (2017) in Democratic Republic of Congo, where 'Gros Michel' scored the highest overall acceptance among the tested dessert-type cultivars also. Pulp of 'Seda' and 'Muquicho' has attractive and rich colour, which probably influenced their overall acceptance (Zuwariah & Aziah, 2009), 'Seda' and 'Muquicho' are generally very popular in Peru (Krauss, 1999). Previously published study of Rivas & Palomina (1986) showed the cultivars 'Seda', 'Muquicho', 'Manzano' and 'Isla' as the most preferred dessert cultivars It exactly corresponds with our result except 'Isla'. Overall acceptance of 'Isla' in our study was the lowest. There is high possibility that our Isla was a different clone. Moreover the study of Rivas & Palomina (1986) was done in Tingo María, which is a part of the district with much higher elevation than Pucallpa and therefore the local consumers´ use patterns and preferences may be different. 'Isla' is multipurpose cultivar, mainly used as baby food, and might not be accepted well by adult panellists due to its toughness (the toughest cultivar in our study) and quite high acidity. It is typical and commonly planted cultivar in Peru, the cultivar is believed to be introduced via Canary Islands but interestingly it has not spread into neighbouring countries to any significant extent (Krauss, 1999). Almost the same cultivars evaluated with overall acceptance were evaluated also as the sweetest: 'Seda', 'Muquicho' and 'Rojo'. Indeed, we found positive correlation between sweetness and overall acceptance in these three cultivars and 'Muquicho'. When we eat something sweet, peripheral receptors in our brains are stimulated, which results in cascade of physiological process causing the strong pleasure response to sweet taste (Fernstrom et al., 2012). The positive hedonic response to sweet taste is universal trait, but it has especially powerful appeal among children and young people (Drewnowski et al., 2012). Our respondents were young people, therefore they were more likely to accept cultivars with high sweetness.

'Manzano' is sought-after for its sour-sweet taste (Krauss, 1999), and in our study was evaluated as the most acid cultivar. However we have not found any significant correlation between acidity and overall acceptance in 'Manzano'. Moreover it possesses specific apple flavour, which gave the cultivar its name. It was also found to be the stickiest cultivar according to the panellists. More precisely, it was the only one persistently sticking to one´s teeth. To the best of our knowledge, rheological properties of 'Manzano' have not been assessed yet in any study. Cultivars 'Muquicho', 'Rojo' and 'Seda' were evaluated as the juiciest. All three of them are used for juice preparation in the Peruvian Amazon. Though 'Seda' is usually preferred, it depends on what is currently available. Slightly higher price of 'Muquicho' makes it more suitable as a snack than for juice preparations, which require higher volume of pulp.

6.3. Local knowledge

The survey of local knowledge revealed several local names for most of the cultivars studied, as the study area is inhabited by people of different origins. According to our best knowledge, the cultivar 'Campeón' was documented for the first time in Peru. We could not find its exact place in international banana nomenclature, as only one name for this cultivar was listed by our respondents. According to its morphology, it is likely to belong to the Bluggoe subgroup.

According to Alves et al. (1987), 'Manzano' can be also found in Brazil, where it is especially common in the central-west and the north regions with a long tradition of its cultivation. In Brazil it is called 'Maçã', which corresponds with Peruvian 'Maca' (Krauss, 1999). Various clones of 'Sucrier', in Peru known as 'Muquicho', are spread worldwide, Shepherd (1957) found that some clones still persist in their original haunts in Southeast Asia, from Malaysia to New Guinea. Our results indicated that 'Guineo' can refer to two cultivars, 'Muquicho and Seda'. Though they look quite different, they have both in common attractive yellow peel and tasty sweet pulp. In case of 'Común', its local name 'Inguiri' may also refer to a dish prepared from unripe banana by boiling it in water with salt (Duke & Martinez, 2018). Knowledge of banana cultivars´ names is vast but not connected, which makes it hard to identify some cultivars from different areas.

Informants reported many uses of the cultivars investigated. Among five categories of preparation types, the “Starch based preparations” was the most represented. Indeed, cooking bananas are of higher importance in human nutrition than dessert-types, because grown as staples they can feed many people (Singh et al., 2014). Starchy bananas are available and cheap staples across the Peruvian Amazon. Tacacho, prepared from the cultivar 'Bellaco' is one of the typical national dishes originating in the area. In the category of preparation types “Fresh”, cultivars 'Seda', 'Manzano' had the highest numbers of records in both, snack and fruit salad. In “Sweet dishes” were mentioned both, dessert and cooking-type cultivars. Mazamorra was reported to be made from 'Bellaco, 'Común' and 'Seda'. Mazamorra has many varieties in Spanish-speaking countries. In Latin America, it is traditionally prepared from maize but also from banana, squash (*Cucurbita* spp.) or the fruit-producing tree *Byrsonima crassifolia* (L.) Kunth. Consistency of Mazamorra may resemble pudding, soup, or even drink. “Mazamorra morada” made from purple maize is typical in Peru. In Colombia, mazamorra from unripe 'Guineo', which may refer to 'Seda' in this study, is consumed as galactogogue food (Vásquez et al., 2014). Purée preparation was reported from ripe 'Capirona', 'Isla' and 'Sapucho' cultivars. It is usually used as baby food. Because the fruit is rich in non-digestible fibres and prebiotic fructooligoscharides, it helps to restore normal intestinal activity (Kumar et al., 2012). Preparations of "Non-alcoholic beverages", especially chapo, are very common in the Peruvian Amazon. Though it is possible to prepare it using several cultivars (e.g. 'Bellaco' or 'Común'), 'Capirona' is the most typical. Use of banana for chifles and flour is common throughout the tropics worldwide. In the Ucayali region, they use mostly plantains in both unripe and ripe stage but 'Capirona' is suitable as well.

6.4. Bananas as medicinal plants

The cultivars were reported to be used as healing plants too. However, details about their use remain mostly under-documented. The fact that younger respondents knew some medicinal uses of particular banana cultivars but were not able to further describe them shows that they have the knowledge, which do not practice frequently thus this part of their traditional knowledge is disappearing (Vlková et al., 2015). Usage of the cultivar 'Común' to ameliorate tuberculosis was reported in the previously published study of Duke and Martinez (2018). Unripe unpeeled fruits are boiled until half of the liquid evaporates, the remaining astringent liquid should drink people recovering from tuberculosis every day for at least six months. In the same book, medicinal use of 'Manzano' was described the same way as 'Rojo' in our results, liquid from pseudostem of cut plant is gathered and consumed against gastritis. Peel of ripe 'Seda' was reported to treat wrinkles, which can be explained by previous study of Matook & Fumio (2005), who found that the peel has an antioxidant and antimicrobial effects. The latter three cases were examples of very specific medical uses, therefore further more detailed studies involving larger sample of informants will be necessary to fully understand local medicinal use patterns.

7. Conclusions

This study aimed to extend knowledge on local diversity of banana in the Peruvian Amazon. Market survey in Pucallpa was conducted in order to describe local cultivars. The cultivars were furthermore investigated for their morphological characteristics, sensory attributes, names and uses. Summarized knowledge was compared to other authors in the field. In the survey, we found out that there were 11 distinct local cultivars. Most of the cultivar´s morphological characteristics were found to correspond with the genomic groups. Colour of some cultivars indicated presence of provitamin A in their pulp.

We found significantly higher consumer´s acceptance in 'Seda' compared to the rest of the cultivars tested. There was positive correlation between sweetness and overall acceptance in most of the cultivars, which showed that sweetness has the greatest influence on overall acceptance among tested sensory attributes.

Informants reported various specific uses of the cultivars, most uses were reported in cooking-type cultivars which highlighted their value in the area. Moreover, some of the cultivars were reported to possess medicinal properties. For example liquid from pseudostem of 'Rojo' can be collected and used for gastritis treatment.

Biggest limitation of this study was relatively small sample of informants and panellists. For the future, pulp colour of some cultivars should be assessed more precisely and eventually tested for the provitamin A content. Also, more detailed research including larger sample of informants and trained panellists could reveal new use patterns of the cultivars investigated, and understand deeper the ones we tried to outline in this work, including their medicinal properties.

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