The Composition of Banana Puree

H.-J. Hofsommer

S. Wallrauch

• Acids • Banana Puree • Carbohydrates • Minerals • Quality

Introduction

Bananas (Musa paradisiaca) are the most widely-traded fruit world-wide along with citrus fruits. The total quantity is somewhere around 55 million tonnes. Table 1 shows the significance of the individual countries of origin, although it includes only those countries producing more than 1 million tonnes. The remainder is accounted for by another 43 countries (1).

It should be mentioned at this point that international statistics include another category "bananas", so-called "plantain". In 1999, world-wide output of this variety, also known as the mealy or cooking banana (2), added up to about 30 million tonnes, around half the dessert bananas quoted above (1). This type, however, is not suitable for making puree.

Interestingly, the main growing countries are not the biggest exporters (1), these being predominantly Latin American countries (figures in brackets = millions of tonnes):

"Irrespective of the type of peeling, there is always the essential problem of protecting the fruit against oxidation to avoid brown discoloration."

Ecuador (approx. 3.0); Costa Rica (approx. 1.8); Columbia (approx. 1.5); Guatemala (approx. 0.8); Honduras (approx. 0.5) and Panama (approx. 0.5). The only major exporting country outside this region are the Philippines (approx. 1.1).

Most of the bananas grown commercially are destined for the fresh fruit market and remain in their country of origin. In Africa, in particular, bananas are considered as an important part of the staple diet. Only a very small proportion (approx. 100 000 tonnes) is used for industrial processing (3). Of this, the alcohol industry and, increasingly, banana puree manufacture are developing into major sectors along with fruit drying. The main purchasers of the purees are the baby food, sweets and beverage industries.

Because bananas are so important, there is hardly a book about tropical and sub-tropical fruits that does not include a chapter about bananas (4 - 8). Most authors report on botanical differences, growth peculiarities, the ripening process, growing conditions, commercial considerations etc. Even in the very comprehensive book "Bananas" (9), there is relatively little information about the chemical composition of bananas or banana purees. Some descriptions were available especially concerning vitamins, aromatic components (4), nutritional value (5) amino acids (14) and minerals (10).

This article aims to fill some of the gaps with results from analyses of authentic purees (i.e. manufactured in our own laboratories on an experimental

Tab. 1: Production Quantity of Banana

	1995	1996	1997	1998	1999
World	56.597.244	55.949.987	59.074.765	55.800.480	58.849.059
India	10.182.000	10.299.000	10.982.000	11.000.000	11.000.000
Brazil	5.906.971	5.844.093	5.412.360	5.324.570	5.527.780
Ecuador	5.403.304	5.726.620	7.494.119	4.563.442	6.392.022
Indonesia	3.805.431	3.023.485	3.057.080	3.176.750	3.165.730
Philippines	3.489.450	3.304.060	3.773.800	3.560.800	3.560.800
China	3.297.636	2.676.588	3.096.736	3.733.814	4.409.883
Costa Rica	2.300.000	2.400.000	2.300.000	2.098.333	2.101.449
Mexico	2.032.652	2.209.550	1.714.457	1.525.836	1.736.728
Thailand	1.750.000	1.750.000	1.700.000	1.720.000	1.720.000
Colombia	1.598.240	1.491.000	1.607.210	1.516.640	1.570.000
Burundi	1.421.407	1.544.498	1.542.640	1.399.143	1.511.370
Viet Nam	1.282.231	1.300.000	1.310.000	1.315.190	1.242.539
Venezuela	944.773	1.026.134	1.122.693	947.651	1.000.394

scale and samples taken by ourselves during commercial manufacture), and others classified as authentic.

The samples originate predominantly from the main growing areas: Costa Rica, Honduras, Ecuador, India, the Philippines, Venezuela and Brazil. Individual samples from Florida, Guatemala, Indonesia, Kenya, Columbia and Vietnam were also analysed.

The total number of samples analysed between 1988 and 2000 was 203. Of these, 35 were made in our own laboratory. As not all parameters were analysed in every sample, the number of samples is given in the tables.

Tab. 2: Organic Acids

Statistical Data*	N	MIN	MAX	MEDIAN	AVG	%-VK
Total acidity g/kg[1] (pH7,0ber.a.WS)	163	1.9	3.9	2.8	2.8	15.0
Total acidity g/kg[1] (pH 8,1ber.a.CS)	164	2.0	3.8	3.2	2.9	13.2
pH-value[1]	103	4.5	5.4	5.1	5.0	3.8
Citric acid g/kg[1]	163	1.6	4.2	2.5	2.7	21.7
Malic acid g/kg	190	2.8	5.1	4.3	3.9	12.8
Iso-citric acid mg/kg	182	50	125	99	83	18.2
citric/Iso-Citric acid	143	21	45	35	33	15.4

Other Acids: see text
L-Ascorbins.(N=158) / Chinas.(N=52) / Shikimis.(N=54) / Fumars.(N=56) / Glucons.(N=56) / Galakturons.(N=53) / Milchs.(N=58)

***)** The statistical evaluation is only based on values within a range of +/- 2s
1) The results are taken from samples without any addition of acids

Banana Puree Manufacture

Banana processing has special features that differ from methods for other fruits. Some issues should be mentioned because they have an inevitably influence the quality and consistency.

Fruit of good quality and right maturity are crucial for manufacturing puree. By contrast with other fruits, puree manufacture is very closely connected with fruit growing, rather than an alternative use for unsold fresh fruits.

As bananas ripen very unevenly on the branch, the fruit destined for processing is also harvested when it is green and ripened in special chambers to ensure the ideal degree of ripeness for the process. The latter is critically determined not only by the organoleptic properties of the bananas, but also by their peelability and, especially, their starch content.

The first stage of processing is the separation of the so-called "fingers" from the stem of the banana palm. After the fingers have been thoroughly washed, the bananas are usually peeled by hand. There are also machines for separating the flesh of the banana from the skin, although hand-peeling invariably gives a higher yield and results in fewer traces of skin being present in the puree.

Irrespective of the type of peeling, there is always the essential problem of protecting the fruit against oxidation to avoid brown discoloration. The traditional method was spraying ascorbic acid over the product as soon as possible. Instead, more modern technologies use protective gases (usually N_2, less frequently CO_2) in the appropriate parts of the machinery to avoid the need for additives. A particularly critical section of the machinery in this respect is the strainer, usually a two-stage operation to obtain a smooth puree. The gauge of the second sieve must not exceed 0.4 mm to ensure removal of the seeds. Degassing of the finished puree is standard nowadays.

Another unique characteristic of banana puree is its pH. This will be addressed in the next chapter in the context of acidity.

A further critical factor, particularly in aseptic filling, is the starch content. The grains of native starch in the banana tend to stick together when heated, causing a rise in viscosity during the cooling phase and filling. Keeping the starch content in the fruit to a consistent low level depends on controlled ripening.

Chemical Composition

Organic Acids

The acid content of bananas is determined entirely by their malic and citric acid content. Other product-typical acids, in particular iso-citric, quinic and shikimi acids are minor components with just a few milligrams (see Table 2).

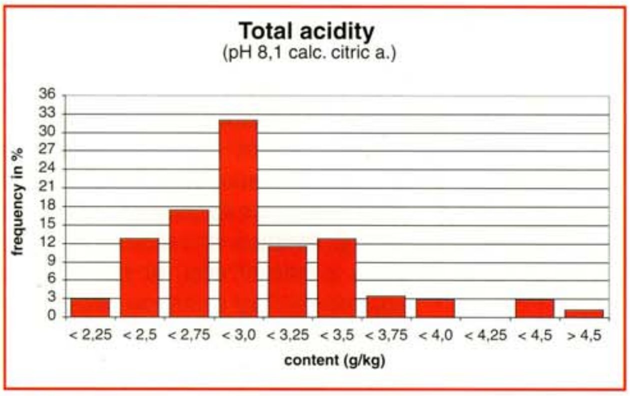

Fig. 1: Frequency distibution: Total Acidity (pH 8,1 a.CS)

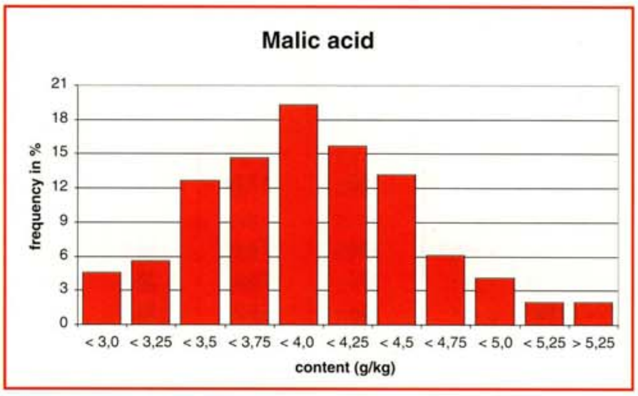

Fig. 2: Frequency distibution: L-malic acid

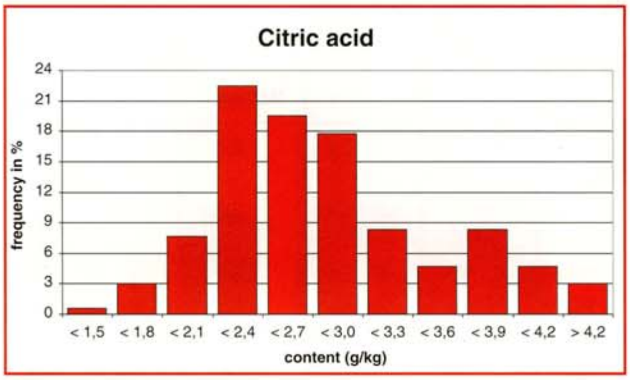

Fig. 3: Frequency of distribution : citric acid

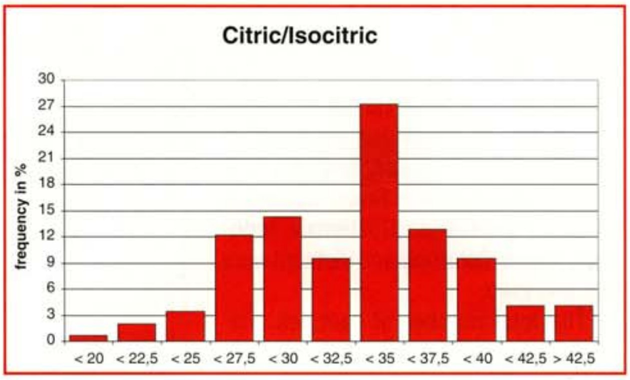

Fig. 4: Frequency of distribution : citric acid/iso-citric acid ratio

Although the malic and citric acid make up a total of about 5 - 9 g/kg, which is comparable to that of other fruits direct edible, the total acidity that can be titrated (pH 8.1 expressed as citric acid) is only 50 % of that. The reason for this is the very high mineral content and the buffer capacity associated with it. The result is that total acidity (pH 7.0 expressed as tartaric acid) is mostly below pH 8.1 expressed as citric acid. The relatively small fluctuation of the Gauss distribution is conspicuous (see Fig. 1). It is probably due to the standardised ripeness of the bananas (see Chapter on Manufacture).

The main acid contained in bananas for processing with the proper degree of ripeness is **L-malic acid**. It generally exceeds the total acidity (pH 8.1 expressed as citric acid) by as much as 2 g/kg, although it must be noted that the difference in 50 % of samples is below 1 g/kg. Citric acid, present in 90 % of samples in a lower concentration than that of malic acid, is similar to the total acidity measured at pH 7.0 (expressed as tartaric acid).

The results from laboratory-prepared samples, many of them with a soluble solid content much lower than that of industrial samples, did not indicate a clearly identifiable "ripeness influence" on malic acid content. The frequency distribution shown in Fig. 2 is typical.

However, as with other fruits, there seems to be a link between the degree of ripeness and **citric acid** content. The less ripe the fruit is in relation to its soluble solid content, the more frequently higher citric acid concentrations were found in the laboratory-prepared samples. These samples have significantly higher levels and were therefore left out of the overall consideration. The citric/iso-citric acid ratio is influenced only slightly by this phenomenon. Typical citric acid contents are shown in Fig. 3.

Tab.3: Sugars

Statistical Data*	N	MIN	MAX	MEDIAN	AVG	%-VK
Brix	200	17.0	24.8	22.1	21.2	7.2
Saccharose g/kg	185	42.0	108.7	78.7	76.0	19.6
Glucose g/kg	183	32.9	72.0	54.4	52.2	14.8
Fructose g/kg	182	32.2	68.0	55.5	50.0	14.36
Starch g/kg	131	0.6	22.4	12.6	10.1	52.9
Total sugar g/kg	188	148	209.5	188.0	179.3	7.2
Sugar-free Extract g/kg	190	17.7â	68.5	40.6	38.7	20.9
%-Saccharose v. total sugar content	184	24.8	59.8	44.0	42.7	17.7
%-Glucose	187	20.4	38.1	30.1	29.1	13.7
%-Fructose	186	19.9	35.9	28.7	28.0	13.0
Glucose/Fructose	185	1.0	1.1	1.0	1.0	1.7

*** The statistical evaluation is only based on values within the range of +/- 2s**

Because it is a commonly-used practice to add citric acid and/or juices rich in citric acid such as lemon or lime juice, special attention must be given to this acid and its identified ratios in authenticity assessment.

The reason for this is the **pH value**, which should be in a range of approx. 4.5 - 5.4 (mean value around 5.0) for a puree without added acids. This means that pasteurisation, the commonly-used method of preserving fruit juices, is insufficient for banana puree, and that temperatures above 100 °C are essential for sterilisation. However, as very high temperatures must be avoided due to the rapid onset of red discoloration, the addition of citric acid is used quite frequently to reduce the pH. The customary addition to achieve a reduction of about 0.5 to 0.7 units to below 4.4 - 4.6 is 1 - 2 g/kg. This is the range generally accepted as safe enough to prevent spore germination.

It is important to note that citric acid as an additive has a technological background and does **not** per se constitute adulteration as is most often the case with other fruit juices or purees. Even though the current laws permit such legitimate additives, declaration is still required by law!

Beside the pH factor just discussed, the iso-citric acid content in relation to citric acid is also a suitable indicator for product control. Fig. 4 shows typical levels. The resulting **citric/iso-citric acid ratio** of less than 45 could be considered natural. Products with added acid would show a ratio of over 40 (mean value approx. 48). This parameter would have to be taken in conjunction with the previously-mentioned criteria (pH; malic/citric acid ratio; L-malic acid as percentage of total acidity; absolute citric acid

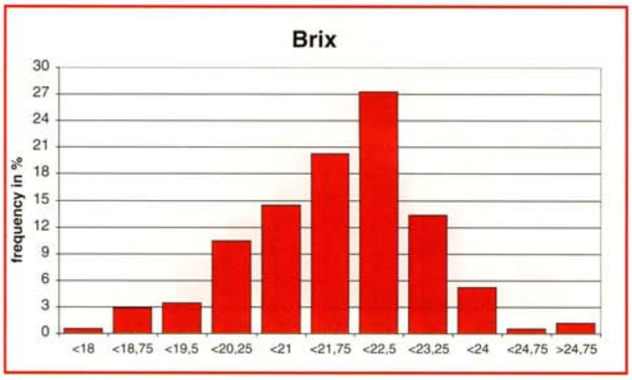

Fig. 5: Frequency of distribution : Brix

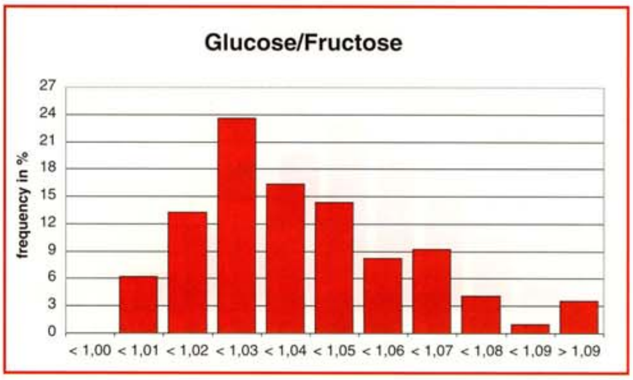

Fig. 6: Frequency of distribution : Glucose/Fructose

content; degree of ripeness) for a true assessment of acid additives or otherwise!

Quinic acid does not occur in any significant quantity. Contents of more than 100 mg/kg are rare. The concentration is often below the detection level of 10 mg/kg. Also free **galacturonic acid** is not present in important amounts. The range can be given with 29-160 mg/kg (mean value around 128)

Shikimi acid occurs only in trace quantities. Normal contents lie between 2 and 30 mg/kg, with an average of about 13 mg.

Concentrations of **fumaric** (< 3 mg/kg), **gluconic acid** (< 100 mg/kg) and **lactic acid** (< 300 mg/kg) the typical indicators of microbial alteration, are insignificant, as might be expected.

With respect to nutritional physiological aspects **ascorbic acid** is only present in unimportant amounts. Of the 35 laboratory-prepared samples, 50 % had concentrations below 10 mg/kg. In the remainder, it was below 30 mg/kg. By contrast with this set, the industrially-made samples have much higher contents. The concentration distribution clearly shows two groups: In about 45 % of the samples, the content is up to 50 mg/kg, while around 70 % of the 84 samples have a content up to 100 mg/kg. The remainder have a content exceeding 150 mg/kg, mostly over 200 mg/kg. Levels above 200 mg/kg were also found in those samples for which added ascorbic acid was declared. Such anti-oxidant additives are common practice for colour stabilisation. Unfortunately, as in the case of citric acid, it is not always properly declared.

Taking into account the literature (11), technology and diversity of cultivars, an ascorbic acid content in excess of 100 mg/kg must be judged to result from added acid. Whether a cut-off limit as low as 50 mg/kg can be established will require further experimentation .

Carbohydrates

Carbohydrate content (see Table 3) is determined substantially by the saccharose, glucose, fructose and starch contents. Due to the technological peculiarity of virtually standardised ripening, the fluctuation range is fairly narrowly limited. The connection between ripeness and substances contained in bananas (particularly sugar and starch) has been widely described (12, 13) elsewhere, and will not be discussed here, as there is no major difference between bananas and other fruits in this respect.

The dissolved solid content (g/100g = **Brix**) is just under 20¡ to 23 ¡ Brix in commercial purees. The frequency distribution shown in Fig. 5 refers to uncorrected Brix. Corrected Brix is not customary in practice. The composition of soluble solids is approx. 80 % sugar and 20 % **sugar-free extract**.

Total sugar content (glucose, fructose and saccharose) ranges substantially from 160 - 200 g/kg, resulting in 30 - 50 g/kg of sugar-free extracts.

About one-third of the sugar-free extract is **starch,** although the proportion is subject to considerable fluctuation. Thus, a content of below 20 % to over 40 % may respectively be given as a third. Even the absolute starch content varies widely and does not fit into a statistical frequency distribution. Contents of over 15 g/kg (approx. 20 % of samples) are just as frequent as contents of less that 15 g/kg (approx. 20 %). It is probably attributable to cultivarspecific and maturity-characteristics.

The total sugar content is made up of about 40 - 55 % **saccharose**, 25 - 35 % **glucose** and 23 - 33 % **fructose**. The **glucose/fructose ratio** as a possible indicator of added sugars rich in glucose or fructose, is just over 1 (mean value approx. 1.04). Ratios below 1 were not identified. Values above 1.08 are very rare (see Fig. 6).

Other sugars such as maltose, maltotriose or sugar alcohols such as sorb-

Tab.4: Minerals

Statistical Data*	N	MIN	MAX	MEDIAN	AVG	%-VK
Ash g/kg	176	6.3	8.5	7.3	7.4	7.0
Potassium g/kg	195	2.9	4.2	3.5	3.5	8.3
Natrium mg/kg	178	0	18	2.7	3.5	98.1
Calcium mg/kg	187	19	94	37.8	42.9	30.0
Magnesium mg/kg	181	220	343	275.4	278.8	9.9
Phosphate mg/kg	121	537	869	686.4	678.1	10.0
Nitrate mg/kg	189	33	249	152.0	140.1	31.1
Chloride mg/kg	56	516	1134	732.3	788.4	21.0
Sulphate mg/kg	54	0	87	4.4	18.1	145.4

*** The statistical evaluation is only based on values within the range of +/- 2s**

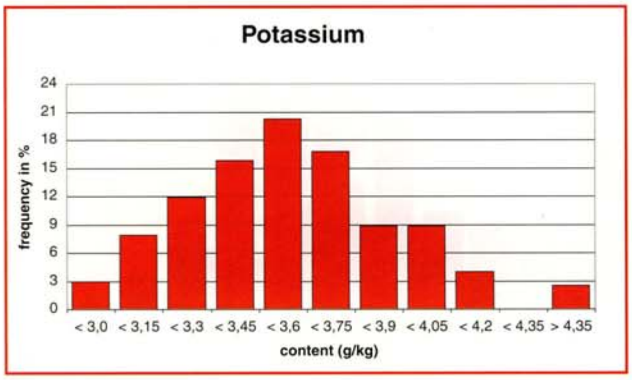

Fig. 7: Frequency of distribution : Potassium

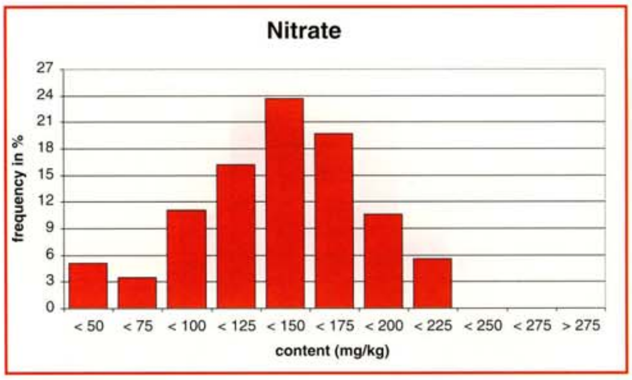

Fig. 8: Frequency of distribution : Nitrate

itol, mannitol, xylitol were not found in commercial purees except in negligible quantities (< 50 mg/kg). Glycerine is also detectable in unadulterated commercial purees in trace amounts only. A content of over 50 mg/kg would appear unusual.

Minerals

Bananas figure prominently among the fruits with a high mineral content (see Tables 4 and 5). **Ash** contents range from 6.3 - 8.5 g/kg. As with other fruits, **potassium** is the predominant element at just below 50 %. Absolute contents are shown in Fig. 7.

The very high **magnesium** content contrasts with most other fruits. No less than 25 % of the analyses show a result of over 300 mg/kg. Average contents are around 275 mg/kg, which is much higher than the concentration in other fruits. Thus, the health value of magnesium from bananas is often emphasised. On the other hand, they are rather low in **calcium** with a content between 30 and 60 mg/kg, and also in **sodium**. A content of 20 mg/kg or more would already tend to indicate the use of unsuitable water and/or additives.

The anionic composition of banana purees has a number of specificities which should be highlighted at this point. In contrast with most other fruits, bananas can store **nitrate**, resulting in very high concentrations. Fig. 8, showing the nitrate distribution explains this conspicuous feature, indicating that values of over 100 mg/kg are perfectly normal. This parameter does not provide grounds for conclusions about the use of unsuitable water.

The same applies in respect of **chloride**. Levels of 600 - 800 mg/kg are not uncommon for bananas. No other fruit is known to have such a high content. There is no recognisable statistical distribution or cause for this unique feature.

Bananas also have a high **phosphate** content (537 – 869 mg/kg). The percentage variation coefficient is surprisingly small at approx. 10 %, indicating a relatively narrow fluctuation. It comes as no surprise, then, that the percentage concentration of phosphate in ash also has a relatively narrow range of 8 - 11 %.

As in most cases, there is no absorption of **sulphate**. Typical levels are below 100 mg/kg. There is no Gauss distribution.

The heavy metals and some other elements analysed (see Table 6) were arsenic, cadmium, mercury, lead, tin, zinc, selenium, nickel and chromium. There were no peculiarities worthy of mention. A 12-year study in the United States of America arrived at similar results, but it also took into consideration Rb, Ls, Li, Ag, Be, La, Ce, Ge, Ti, Zr, Sb, Bi, Tc and Al (10).

Tab.5: Ratio of minerals

Statistical Evaluation*	N	MIN	MAX	MEDIAN	AVG	%-VK
Alcalinity Number	56	9.4	13.3	11.9	11.4	8.3
Potasium-Magnesium-Ratio	189	8.9	16.7	13.2	12.7	13.1
Potassium-Calcium-Ratio	185	33.6	144.4	105.6	87.3	27.5
Magnesium-Calcium-Ratio	182	2.9	10.9	7.3	6.8	24.0
%-Potassium in Ash	109	43.9	51.7	49.0	47.7	3.4
%-Phosphate in Ash	107	7.2	11.1	9.4	9.2	9.6
%-Chloride in Ash	57	7.1	14.8	9.8	10.6	20.2
%-Nitrate in Ash	185	0.5	3.4	2.1	1.9	30.5

*** The statistical evaluation is only based on values within the range of +/- 2s**

Amino Acids

Table 7 shows the amino acid contents. Although the information given by results of this kind of analysis are not always credited with their rightful priority in the assessment of fruit juices and purees, there is a feature peculiar to bananas that needs to be highlighted here. Their high **histidine** and **leucine** content is characteristic to bananas and can be used as an indicator of banana in blended drinks. Another typical indicator is the high **valine** content. After all approx. 80% of the samples range over 1 mmol/l. If this is at issue, the starch content is also often helpful.

Based on the distribution indicated, the amino acid pattern is useful for accurate assessment. To this end, the relatively low **proline** content (< 100 mg/kg; mean content 50 mg/kg) should be mentioned, which can increase when other juices are added.

Tab. 6: Heavy metals and other elements (ppm)				
	N	MIN	MAX	MEDIAN
Manganese	49	<0.01	4.5	1.3
Eisen	63	<0.05	3.7	0.6
Cadmium	91	<0.001	0.010	0.002
Lead	93	<0.005	0.05	0.025
Zinc	70	0.15	1.5	0.75
Copper	70	0.12	0.8	0.47
Nickel	53	<0.01	0.1	0.031
Chromium	53	<0.005	0.05	—
Arsenic	78	<0.002	0.012	<0.002
Selenium	18	—	<0.002	—
Antimony	6	—	<0.002	—
Mercury	29	—	<0.001	—

Tab. 7: Free amino acid (values indicated in mmol/kg) (including Ammonia and Formole)						
Statistical Data*						
	N	MIN	MAX	MEDIAN	AVG	%-VK
Aspartic acid	147	0.17	1.25	0.76	0.68	34.4
Threonine	147	0.21	0.65	0.41	0.43	23.0
Serine	146	0.90	1.84	1.42	1.40	16.0
Asparagine	145	1.55	5.54	3.35	3.39	25.8
Glutamic acid	143	0.01	0.25	0.02	0.05	116.1
Glutamine	147	0.01	7.20	3.25	2.99	60.3
Proline	151	0.01	0.92	0.42	0.39	62.8
Glycine	142	0.18	0.81	0.46	0.46	26.7
Alanine	146	0.01	0.99	0.45	0.46	42.1
Valine	152	0.33	3.90	2.65	2.04	45.0
Methionine	150	0.01	0.11	0.02	0.02	89.0
Isoleucine	148	0.01	0.26	0.12	0.12	48.2
Leucine	148	0.90	3.86	2.82	2.48	26.4
Tyrosine	144	0.01	0.61	0.22	0.23	55.9
Phenylalanin	146	0.01	0.32	0.12	0.11	59.3
Amino butyric ac.	145	0.48	2.50	1.59	1.46	30.9
Ethanolamine	152	0.01	0.39	0.03	0.11	92.4
Ammonia	149	0.04	5.81	3.21	2.88	50.6
Ornithine	151	0.01	0.14	0.02	0.02	108.9
Lysine	147	0.20	0.89	0.51	0.53	29.7
Histidine	148	2.46	5.88	4.34	4.11	20.0
Arginine	147	0.37	2.34	1.45	1.27	32.0
Total amino acid	145	15.75	32.39	24.90	23.92	16.4
* The statistical evaluation is only based on values within the range of +/- 2s						

As with most other fruits, there is a Gauss distribution for individual amino acids. The fluctuation ranges are all quite large, however. This means that the formol content and total amino acid vary within a wide range.

Summary

Based on approx. 200 authentic samples, or others classified as authentic an overview is given on the composition of banana puree from the main growing countries. The following main groups were analyzed: Organic acids, carbohydrates, amino acids and minerals.

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Authors: Dr. H.-J. Hofsommer; GfL Gesellschaft für Lebensmittel-Forschung mbH, D-10787 Berlin, Dr. S. Wallrauch; Landesuntersuchungsamt für das Gesundheitswesen Nordbayern, D-97082 Würzburg