Faculty of Food Science

CONNECTION BETWEEN THE FRAGRANCE CONSTITUENTS AND THE BOTANICAL ORIGIN OF UNIFLORAL HONEY SPECIALITIES

THESIS OF THE Ph.D. DISSERTATION

of

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The applicant met the requirement of the PhD regulations of the Corvinus University of Budapest and the thesis is accepted for the defence process.

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1. INTRODUCTION

Honey that has served as nourishment to humans since the prehistoric times came into scientific limelight recently. One of the main reasons of this phenomenon is that more and more people consume foods of „natural origin" also honey for instance, acting either fashionably or from conviction. That is why the investigation of its composition, *e.g.* expected active agent and possible contaminant content is of significance.

The other cause of investigations is the increasing frequency of the honey adulteration. Adulterators have a wide scale of opportunity, because giving scientific evidence of honey authenticity is almost impossible in certain cases. These cases include the intentional mislabelling of honey provenance and floral source as well. Honey authenticity has to be examined from two main aspects. First is judging if honey derives merely from the sweet fluids of flowers and plants collected and converted by honeybees. On the other hand it is considered adulteration too if the geographic or botanical origin is not identical to the labelled one on the bottle. Improper production and treatment techniques *e.g.* overheating can not be considered adulteration.

The taste, scent, mineral content and the curative effect of the honeys, that is, their all beneficial features depend on the derivation that determines the price as well. Unifloral honeys cost more than multifloral ones and prices of the not easily collectable, rarely appearing in the market kinds of honeys are always the highest.

Hungary is a big honey manufacturer compared to its size of territory. It produces 15-18 thousands of tons of honey a year that is approximately 10 % of the EU's consumption. In the years about 2000 nearly one percent of the whole World Production was manufactured by Hungary. Unfortunately Hungarian honeys are not given the appreciation they deserve mainly owing to the barrel packaging, that means the majority of our production is transported and sold abroad without labelling the (uni)floral origin. Thus Hungarian honey producers can enjoy neither the financial nor the ethical benefits of their outstanding product. None of the Hungarian honeys are protected by EU regulation [Council Regulation (EC) 510/2006 on the protection of geographical indications and designations of origin] though the majority of them are excellent and bear constant and balanced quality with outstanding organoleptic features.

Manipulation of honeys could be restricted or even prevented and stopped if their floral or/and geographic origin succeeded in being proved undoubtedly. Authentication of this type will never be of 100 % reliability since honeybees collect nectar of slightly different composition from the same bee pasture year by year, the main cause of what is the change of weather circumstances. Under dry weather conditions certain plants, for example the linden, give little nectar thus honeybees visit other flowers as well. In hot years certain plants may "co-flower" with others the blooming of which separates otherwise (*e.g.* false acacia and rape), in rainy weather aphids and

scale insects pullulate on the trees nearby and bees can collect honey-dew too. In spite of the above problems honeys designated unifloral (those ones whose majority was collected as a sole/single plant's nectar) bear constant features easily recognizable. Thus chance for the identification of the botanical source there exists in the cases of monofloral honeys only.

The amounts and ratios of pollen found in the honeys have been accepted for a long time as a proof of origin. Though honeys' pollen composition is a good clue relating to the derivation, – it is unimaginable for instance that a false acacia honey does not contain *Robinia* pollen at all, – it must be considered that pollen-ratios do not reflect the nectar-ratios truly. There are plants whose visit does not provide the bees with pollen (on account of the exceptional structure of the bloom). So *Robinia* honey for example can excellently be adulterated with common milkweed *(Asclepias syriaca)* honey, since milkweed honey does not contain pollen at all and resembles the previous one in its other features as well.

Investigations aiming at the identification of unifloral honeys are conducted in two main directions recently. One of them measures as much physical and chemical parameters (colour, conductivity, sugar-composition, viscosity, amino acid and flavonoid content *etc.*) as possible and differentiates the monofloral honeys by statistical methods. This solution requires enormous databases of the determined characteristics and gave modest results merely, making possible only little basic discernment (*e.g.* the higher glucose/fructose ratio of *Robinia* honeys, the higher inorganic ion content of honeydew honeys, the high prolin content of natural honeys, all are characteristic). The other method seeks for marker compounds that is compositional features that individually characterize the unifloral honey in question. Investigations generally aim at finding such characteristic components whose presence or absence undoubtedly proves the origin of the honey. Substances of this kind are the ones that pass through from the nectar to the honey. Primarily, they are volatile constituents (mainly terpenes, their derivatives and carotinoide decomposition products) as well as plant colour materials mostly flavonoids and phenolic substances. Marker (individually characterizing, absent from all other honeys) compounds of several unifloral honeys are reported in the Literature. Partly because the honey in question is purchased/sold in large quantities and is very popular the adulteration of what may cause huge losses, partly because it is a real rarity or possesses special features *e.g.* curative effect, the purity of that is intended to be guaranteed by the vendor. (Honeys of these type for instance are the French „label rouge" lavender honey originating from *Lavandula angustifolia* nectar mostly and that must not contain *Lavandula stoechas* nectar at all, or the New-Zealand manuka honey that has got medically proved wound-curing effect, or the detection and identification of rhododendron-nectar the honey of which is poisonous.)

2. OBJECTIVES

The goal of my PhD. dissertation/work was the investigation of the aroma-composition of the following unifloral honeys: linden (*Tiliaceae*) honey, outstandingly important in Hungary's honey production for its medicinal effect and its manufactured amount; goldenrod (*Solidago canadensis*) honey for the same reason; lavender (*Lavandula angustifolia*), *Limonium* (*Limonium, gmelinii*, WILLD) and elderberry (*Sambucus, nigra*) honeys, the latter three ones are honey curiosities in our country.

The measurements aimed at two purposes. On one hand they furnished data on honeys' aroma-composition like goldenrod, limonium and elderberry whose scent features have not been described yet. On the other hand they served the search for aroma compounds individually characteristic of the monofloral honey in question.

The working hypothesis was that the fragrance components of the honey reflect the scent features of the flower thus aroma compounds of the source flowers have been searched for in the honeys. So, aroma-extracts prepared from the flowers and their honeys have been analysed and evaluated in the experiments.

The above analysis required the development of an extraction method capable of representing the aroma composition of the flowers truthfully, and that is suitable to extract and properly enrich the characterizing volatile components of honeys having essentially disparate composition, in order to perform the chemical comparison of the scents.

After gas chromatographic separation the extracts have been examined by mass spectrometric detection. Then the recorded chromatograms were analysed and evaluated with our method developed in research-fellow relationship, elaborated prior to the honey investigations.

The aim of the investigations was also to reveal if the aroma-composition of the honeys change year by year to such an extent which obstructs recognisability and identification. Consequently, if any chance occurred, honeys of the same kind of different vintages and flowers deriving from different years have been compared too.

The final goal of the data evaluation was to prove the similarity of the honey to the source flower but the sufficient individuality of the aroma-spectra to verify identity has to be controlled as well. Thus the comparison of the found constituents and recorded aroma-spectra with the honey aroma descriptions published in Literature was of primary aim to certify individuality.

Summarizing therefore, the main goals of the work were as follows:

- The extraction of the aroma-compounds of unifloral honeys (honey of presumably known origin) and that of the source flowers.
- The identification of the extracted compounds.

- Revealing the common component-set by comparing the flowers' constituents to that of the honey.
- Designation the marker compounds among the common substances by the presence of whose the origin of the honey can be proved.

3. MATERIALS AND METHODS

3.1. Materials

3.1.1. Samples examined

The measurement of all honeys has been carried out in the year of extraction to prevent the influence on the results of the aroma compounds' changes during storage. The blooms were picked in the year of the honey collection generally, in some (indicated) cases in the next one. By the time the late-extracted honeys (*Solidago*) get to be sold, flowers wither or start to, and both the quality and the quantity of the scent compounds might change substantially.

Linden honeys: The samples derived from the Cserhát district from the years of 2000. and 2001, by the courtesy of Hungaronektár where the microscopic and pollen analysis of them have also been performed. According to the results the examined honeys were of 70 % and 89 % pollen percent quality.

Linden blossoms: The samples were picked in 2000 in Budapest from the *Tilia cordata* Mill. and „co-flowering" *Tilia platyphyllos* species.

Limonium honey: The samples were manufactured by a beekeeper living near to the city Gyula, in 2001. In that drought year his bee families settled on sunflower pasture could not collect from the target plant but the *Limonium* flowers bearing aridity excellently and blooming nearby abundantly. Thus a very special uniqueness „limonium-honey" took birth, that he offered us to be examined because of its sour-bitter taste character that can be considered curiosity.

Limonium (*Limonium gmelinii*): The samples were picked nearby Gyula in the bee pasture mentioned above in the years 2001 and 2002.

Goldenrod honey: *Solidago* honeys derive from 2005 and 2006 and were produced by a beekeeper living near to the city Győr in the gallery of Rába river. In this place goldenrod blooms abundantly practically as a single plant in the second half of the summer.

Goldenrod (*Soligago canadensis)* flower: The flowers were collected in 2005 and 2006 from the bee pasture described above.

Sambucus honey: The sample originates from the Hűvösvölgy district from the year of 2003 by the courtesy of a primary producer. As he explained, there was no other blooming plant but elderberry (*Sambucus nigra*) during the collection and the speed of the collection was so high that he had to extract the honey. Therefore the majority of it derives from elderberry, presumably.

Elderberry flower: The blooms of a cultivated variety *i.e. Sambucus nigra* L. cv. *Haschberg* have been investigated from the year 2004. This species is typically fragrant.

Lavender honey: The sample was purchased from a primary producer pasturing in the inner basin of Tihany peninsula. The vintage of 2003 has been examined.

Lavender flower: To ensure comparability, according to the beekeeper's instruction lavender blooms were picked in the same field where the nectar was collected from *Lavandula angustifolia* in the previous year.

3.1.2. Chemicals

- n-pentane anal. grade Reanal
- distilled water double distd.
- Internal stand: 1-undecanol anal. grade Merck
- All other chemicals used in the experiments were of highest purity available, purchased from Reanal.

3.2. Methods

3.2.1. Sample preparation

- Preparation of the flower samples:

Likens-Nickerson simultaneous distillation-extraction (SDE):

3x200 g flower

900 cm^3 dist. water

0,8 mg ISTD

180 g NaCl

distillation against 200 cm^3 pentane

dehydration by freezing

evaporation to 1 cm^3 end-volume

1 microliter to GC-MSD measurement

- Preparation of the honey samples:

3x200 g honey

50 cm^3 ethanol

0,8 mg ISTD

distillation

dehydration of the distillate, extraction with pentane in separation vessel

Distillation residue to Lickens-Nickerson SDE similarly to the blooms' operation.

The two organic phases united, evaporation to 1 cm^3 end-volume

1 microliter to GC-MSD measurement

3.2.2. Gas chromatographic separation

- Equipment:

  Hewlett Packard 5890/ II GC - 5971 A MSD

  Capillary column: 60 m x 0,25 mm Supelcowax 10 (fused silica) 0,25 μm film thickness

- GC-MS conditions:

Starting temperature:	T_1= 60 ^{0}C
Temperature program:	v_f = 4.0 ^{0}C/min
End temperature:	T_2= 280 ^{0}C, t_2=10.00 min
Detector temperature (transfer line):	T_{det} = 280 ^{0}C
Carrier:	He (4.6), lin. vel..: 30.0 cm/s
Injector:	mode: splitless,
	P_{in}=160 kPa
Injector temperature:	T_{inj}=270 ^{0}C
Injector mode:	split, delay: 0.35 min.
Split ratio:	100:1
Mass range	m/z = 25-350
SCAN speed:	390 D/s
Injected volume:	1 μl

3.2.3. Evaluation method

The gas chromatographically separated scent and aroma compounds have been detected with mass selective detector (MSD). The identification of the components was carried out with the WILEY 275.L, NIST05.L, WILEY138.L, NBS49K.L spectrum-libraries individually (in manual mode) compound by compound. The absolute gas chromatograms have been converted into fragrance-graphs by the relative aromagram-construction method.

4. RESULTS

In solving the analytical task an extraction method applying undecanol-1 internal standard addition prior to Likens-Nickerson simultaneous distillation-extraction (SDE) has been developed to prepare the flower and honey samples for measurements. After polar phase (Supelcowax 10) capillary column gas chromatographic separation the sample extracts were analysed by mass spectrometry in details. All constituents were individually identified applying proper background compensation matching the best to the case in hand. The GC-MS results have been converted into aroma-spectra by the relative aroma-construction method, substituting the data of the horizontal axis with the programmed temperature retention indices (PTRI) related to the elution times of the normal alkanes, and substituting the data of the vertical axis with the relative intensity values (Rel. Int. %) related to the internal standard's peak area. Thus the results *i.e.* aroma-graphs become free of the majority of the distorting effects (*e.g.* proportional distortions and changes of measuring conditions).

The marker-compounds of floral origin have been designated by their PTRI values that do not depend on the conditions of the measurement – it is inevitable for the recognition as well on the account of the great number of isomer structures occurring – and have been identified. Thus the possibility of verifying the botanical origin of the honeys examined has been created.

In the cases of linden, *Sambucus* and goldenrod honeys marker components common in the honey and the flower obeying the assumption presumed by the working hypothesis has been found.

Tilia:

Both in the flower and in the honey more than 120 constituents were identified. Of them common compounds suitable to prove the linden-derivation were found, they are the next (PTRI in parentheses):

- Dill ether (1518)
- Linden ether (1673)
- Chrysanthenon (1817)

Sambucus:

In the flower 80 and in the honey 106 substances were identified. A part of the exceptional constituents derives from bee-repellent (smoker), I presume. Their occurrence shows the extreme sensitivity of the measurement. Among the common compounds the following ones can bee considered markers:

- trans-rose oxide

- hotrienol

Solidago:

In the flower 54 and in the honey 88 substances were identified. The wealth of sesquiterpenes is the consequence of the special germacrene-metabolism of the plant (*Solidago* can synthesize this substance by both mevalonate- and methylerithritol-cycle, thus both optical isomers appear). Components that fit identification are as follows:

- delta-elemene (p-menth-3-ene, 1486)
- beta-elemene (1619),
- alpha-amorphene (1677, 1799),
- germacrene-D (1745),
- delta-cadinene (1792).

In the cases of *Limonium* and lavender honeys no common compounds existed that could have proved the connection individually. Otherwise, the excellent match of the results of the investigated flower and honey pairs year by year precluded the chance of measurement mistakes. The absence of markers can sufficiently be interpreted and understood by my next explanation:

1. Fragrances produced by the flowers to attract the insects are synthesized in different biochemical syntheses and organs compared to the nectar that is intended to have the honeybees pollinated the flowers spontaneously when it is consumed by them. Even if these organs are close to each other depending on the individual structure of the bloom (it changes species by species) the question remains if the relatively concentrated sugar solution is able to solve enough plant characterizing terpene and derivative compound almost unsolvable in water. It might happen thus that the marker components do not pass through into the nectar, consequently the honey can not bear the character of the botanical source.
2. At the 40-45 ^{0}C temperature of the beehive honeybees suck up and pump back the nectar several hundred times ventilating it by their wings to concentrate and ripen it into honey. In this process the components are exposed to a steam distillation effect identical to the one applied by us at 100 ^{0}C, but at 40-45 ^{0}C only. The loss caused by the above phenomenon might lower the amount of components to an undetectable level, though the designation „*marker*" means individual characteristic not quantitative one.
3. At the temperature of the beehive in the concentration process labile substances may decompose.
4. Original marker constituents convert into non characteristic derivatives, *e.g.* terpene alcohols of great scent activity into inactive terpene oxide compounds.
5. During storage, under the influence of high sugar amount's equilibria modifying ability and

the catalytic effect of natural acid content, terpene alcohols suffer a change into scent-inactive terpene-glycosides of low volatility from sample preparation point of view.

6. The honey thought to be connected to a definite flower source is in fact honeydew honey.

In spite of the acceptance of the arguments above, individually characteristic compounds – though not common with the flower – could be found that seem suitable for the identification of the honey.

These are the following ones:

Limonium:

- veridiflorol (2205)
- atisirene (2345)
- rimuene (2763).

Lavender:

- dill ether (1518)
- 5-isoprenyl-2-methyl-2-vinyltetrahydrofuran I., II. (Herboxide I. és II., 1205, 1232).

In all honey samples at great retention times low volatile substances of non plant origin have been detected. They are constituents of pheromone character and could get into the honey as derivatives of communicative/signing agents of insects. They appeared in the honeys only, so their artefact existence can be excluded. The identified components were the next:

- Linden honey : (+-)-15-hexadecanolide, hexadec-7-ene-16-olide, (muscambrett),
- Limonium honey: (Z)-octadec-9-ene-18-olide, docosanolide,
- Lavender honey: oxacycloheptadec-8-ene-2-on (ambrettolide),
- Sambucus honey: hexadec-7-ene-16-olide (muscambrett), (Z)-octadec-9-ene-18-olide,
- Solidago honey : oxacycloheptadec-8-ene-2-on, hexadec-7-ene-16-olide (muscambrett).

Their detection became possible partly owing to the longer than the usual chromatographic run, partly on account of the high sensitivity of the measurement and sample preparation.

5. NEW SCIENTIFIC ACHIEVEMENTS (THESES)

The aim of the work was the authentication of unifloral honey specialities' origin, namely the honey of lime tree, elder, Limonium and goldenrod. The task has been made by revealing the chemical relationship between the flower and its honey and by searching for unique marker compounds that prove the honey provenance, that is the flower source.

The new scientific and methodological results are as follows:

- Development of a Likens-Nickerson simultaneous distillation-extraction method using undecanol-1 internal standard for the extraction of the volatile compounds of flowers and their honeys. Gas chromatographic separation and mass spectrometric identification of peaks and subsequent evaluation of the recorded total ion chromatograms (TICs) with individual manual-mode identification procedure (applying appropriate background compensation) of each constituent and search for common components in honey and flower.
- Definition of candidate marker compounds by analysing the common compound-set of honeys and their flower. Specification of the conditions of chemical identification (compound names, elution parameters, that is the PTRI-s) of the unifloral honeys dealt with. Composition of a computerizable algorithm as a decision table for the identification of the honeys.
- In case of Limonium and lavender (and highly possibly in other cases as well) demonstration (against the prevailing opinion) that the honey is not necessarily bears the chemical marks of the source flower. This phenomenon is explained theoretically in six paragraphs. According to the whole data-set of measurements and literature data, the two mentioned honeys had been characterized by unique chemical compounds in spite of the fact that they do not have common markers with the flowers.
- Relying on results gained by the relative aroma spectra method (which has been designed by our research team of Department of Food Chemistry and Nutrition) proof has been acquired for the year-to-year identity of flowers' and their honeys' scents. The scent pattern is measurable and achievable for later identification tasks by the method worked out in the present dissertation.
- It also has been proved by the relative aroma patterns that the flower's and the resulting honey's aroma spectra are not similar and that of honey's cannot be deduced from the flower's. The cause is the loss of volatiles during the ripening of nectar to honey because of evaporation, conversion and degradation.
- At high retention times of the aroma chromatograms new compounds, not having been reported by the literature, have been identified. These "olide" compounds bear chemical information for honeybees and other insects. These compounds are presumably derivatives of bee pheromones. (Honeybees put their chemical stamps on the flowers having been visited and have chemical signs identifying their kin of the same beehive or the presence of the queen.)

6. LIST OF PUBLICATION RELATED TO THE DISSERTATION

6.1. Articles in journals

Journals with impact factor, foreign language

1. Földházi, G., Amtmann, M., Fodor, P., Ittzés, A.: The Physico-Chemical Properties and composition of Honeys of Different Botanical Origin, Acta Alimentaria, Vol. 25. (3), pp. 237-256., 1996. **(cited 4 times)**
2. Korány, K., Amtmann, M.: GC-MS Measurements in the Investigation of Pepper Aroma Structures, Rapid Communications in Mass Spectrometry (RCM), Vol. 11., pp. 686-690., 1997. **(cited 4 times)**
3. Korány, K., Mednyánszky, Zs., Amtmann, M. : Preliminary Results of a Recognition Method Visualizing the Aroma and Fragrance Features, Acta Alimentaria, Vol.29., pp. 187-198., 2000. **(cited 2 times)**
4. Kocsis, N., Amtmann, M., Mednyánszky, Zs., Korány, K.: GC-MS Investigation of the Aroma Compounds of Hungarian Red Paprika (Capsicum annuum) Cultivars, J. of Food Composition and Analysis, 15, pp. 195-203., 2002. **(cited 10 times)**
5. Kocsis, N., Márkus, F., Mednyánszky, Zs., Amtmann, M. and Korány, K.: Recognition Experiments of the Vintage 1997 Year Hot and Red Paprika (Capsicum annuum L.) Varieties Grown in Kalocsa, Acta Alimentaria, Vol.32. (1)., pp. 61-73., 2003. **(cited 2 times)**
6. Kasper-Szél, Zs., Amtmann, M., Takáts, A. and Kardos-Neumann, Á.: A Comparative Analysis of Hungarian Robinia and Milkwed Honeys Based on Their Chemical and Physical Characteristics, Preliminary communication, Acta Alimentaria, Vol. 32. (4)., pp. 395-403., 2003. **(cited once)**
7. Korány, K and Amtmann, M.: A Practical, Theory Supported Approach of Linear Temperature Programmed Gas Chromatographic Retention Indices Used in the Recognition Experiments of Hungarian Food Specialities, Called "Hungarics", J. of Food Composition and Analysis, 18, pp. 345-357. 2005. **(cited 2 times)**
8. Kornél Korány, and Mária Amtmann: Journal of Food Composition and Analysis: 19(8) December 2006, pp. 813-821: An experimentally supported, mathematical explanation of the gas chromatographic elution behaviour of the long-chain carbon members of the homologous series. **(cited once)**
9. E. Majoros, M. Csóka, M. Amtmann, K. Korány: Comparison of the volatile compounds of fresh and dried apricot fruits by GC-MS measurements: Acta Alimentaria: 37(2) pp.271-282 (2008) **(cited once)**

10. M. Amtmann: The chemical relationship between the scent features of goldenrod (Solidago canadensis,L) flower and its unifloral honey. Journal of Food Composition and Analysis (in press)

Journals with impact factor, Hungarian language

11. Korány Kornél, Amtmann Mária: A normál alkánok elúciós viselkedésén alapuló retenciós index rendszerek egy lehetséges elméleti leírása. Magyar Kémiai Folyóirat: 114 (1), pp.15-20 (2008)

Journals without impact factor, foreign language

1. Mednyánszky, Zs., Amtmann, M., Korány, K.: Application of Mass Spectrometry Principles for the Investigation of Pepper Aroma Profile, Publ. Univ. Horticulturae Industriaeque Alimentariae Vol. LVII. pp. 19-21. , 1998.
2. Amtmann M., Szabó S. A., Korány K.: Application of floral scent analysis in the verification of honey authenticity, Journal of Food Physics XXI. pp. 7-9, 2008.

Journals without impact factor, Hungarian language

1. FÖLDHÁZINÉ R. G., AMTMANN M., KISS T. (1996): Fajtamézek fizikai és kémiai jellemzése I. Méhészet, 44 (3) pp. 14-15.
2. FÖLDHÁZINÉ R. G., AMTMANN M., KISS T: (1996): Fajtamézek fizikai és kémiai jellemzői II. Méhészet, 44 (4) pp. 10-11.

6.2 Publications in conference abstracts

Hungarian abstracts

1. Amtmann, M., Korány, K. : Fűszerek aromaanyagainak kapilláris gázkromatográfiás vizsgálata (Lippay János Tudományos Ülésszak, 1990 nov. 7-8.)
2. Amtmann, M., Korány, K. : A bors aromakomponenseinek azonosítása GC-MS módszerrel (251. KÉKI Kollokvium 1991, június 28.)
3. Korány, K., Amtmann, M. : A bors minőségének gyors ellenőrzése (poszter), Az élemiszerellenőrzés IX. Tudományos Konferenciája, 1991, szeptember 26-27. Nyíregyháza.
4. Amtmann, M., Korány, K. : Bors illó komponenseinek mérése besőstandard addicióval,

Lippay János Tudományos Ülésszak, 1992 november 4-5., Budapest KÉE.

5. Korány, K., Amtmann, M.: Nyers kávéminták felismerése a kereskedelmi minták kivonatainak gázkromatográfiás mérése alapján, Vas Károly Tudományos Ülésszak, 1996. november 21-22., KÉE Budapest.
6. Korány, K., Amtmann, M., Mednyánszky, Zs.: Az aromaspektrum szerkesztési eljárás hasonló sokszög módszerré fejlesztése programozott hőmérsékletű retenciós index mérések segítségével, Lippay János – Vas Károly Nemzetközi Tudományos Ülésszak, KÉE. Budapest, szeptember 16-18., 1998.
7. Amtmann, M., Mednyánszky, Zs., Tolnay P., Korány, K.: Fajtamézek illatkomponenseinek vizsgálata (poszter), Vas Károly Tud. Ülésszak, Budapest 2000. nov.6-7.
8. Kocsis, N., Amtmann, M., Mednyánszky, Zs., Korány, K.: Kalocsai termesztésű fűszerpaprikák aroma-alkotóinak összehasonlítása GC-MS mérésekkel, Vas Károly Tud. Ülésszak, Budapest 2000. nov.6-7.
9. Amtmann, M., Mednyánszky, Zs., Kasperné, Szél, Zs., Korány, K.: Mézek illatkomponenseinek GC-MS eredetvizsgálata, Lippay János – Ormos Imre – Vas Károly Tudományos Ülésszak, Budapest, 2003. november 6-7, Budapest, pp. 178-179.
10. Amtmann, M., Kereskényi, É., Kétszeri, D., Korány, K.: Méz mintaelőkészítési módszerek összehasonlítása GC-MS mérésekkel, Lippay János – Ormos Imre – Vas Károly Tudományos Ülésszak, Budapest, 2003. november 6-7, Budapest, pp. 180-181.
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