

United States Department of Agriculture
Agricultural Marketing Service | National Organic Program
Document Cover Sheet

<https://www.ams.usda.gov/rules-regulations/organic/petitioned-substances>

Document Type:

National List Petition or Petition Update

A petition is a request to amend the USDA National Organic Program's National List of Allowed and Prohibited Substances (National List).

Any person may submit a petition to have a substance evaluated by the National Organic Standards Board (7 CFR 205.607(a)).

Guidelines for submitting a petition are available in the NOP Handbook as NOP 3011, National List Petition Guidelines.

Petitions are posted for the public on the NOP website for Petitioned Substances.

Technical Report

A technical report is developed in response to a petition to amend the National List. Reports are also developed to assist in the review of substances that are already on the National List.

Technical reports are completed by third-party contractors and are available to the public on the NOP website for Petitioned Substances.

Contractor names and dates completed are available in the report.

National List Petition

Use of Magnesium carbonate hydroxide E504(ii) as a processing aid in the manufacture of the soluble extract of organic chicory

Petitioner : LEROUX
84 rue François Herbo
59310 ORCHIES
FRANCE

Context :

Leroux company is specialized in the transformation of chicory root (*Cichorium intybus L.*) in the form of instant product (instant drinks).

Chicory roots washed, sliced, dried, roasted, milled, sieved, and extracted with hot water. Instant chicory powder is obtained by dehydration (spray drying) of this chicory liquid extract.

Leroux has been processing chicory root for over 160 years. <https://www.leroux.com/en>

However, during our last processing steps: atomization and packaging, the instant chicory powder tends to stick to the walls of the installations. This leads to many stops for cleaning and therefore a reduction in production rates. These phenomena are explained by poor fluidity of the powder and therefore a low flow index. In order to overcome this problem, Leroux uses magnesium carbonate hydroxide, authorized in conventional agriculture. We would like this technological aid (magnesium hydroxide carbonate) to be included in the list of technological aids authorized in organic products.

Item A.1 — Indicate which section or sections the petitioned substance will be included on and/or removed from the National List. The current National List may be viewed at www.ams.usda.gov/NOPNationalList.

Name of additive / substance	Primary use/conditions
E504(ii): Magnesium hydroxide Carbonate	Drying agent / Anti-caking agent
§ 205.605: Nonagricultural (nonorganic) substances allowed in or on processed products labelled as “organic” or “made with organic (specified ingredients)”.	

Item A.2

OFPA Category	Processing aids
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Item A.3

Inert Ingredients	Non applicable
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Item B—Information on the substance being petitioned

Item B.1. Substance Name

<i>Chemical name(s)</i>	Magnesium hydroxide carbonate Magnesium carbonate hydroxide hydrated
<i>Other names</i>	(ii) NA
<i>Trade name</i>	Magnesium hydroxide carbonate
<i>Synonyms</i>	INS No. 504(ii)
<i>Definition</i>	Magnesium carbonate hydroxide hydrated
<i>C.A.S. number</i>	12125-28-9
<i>Assay</i>	Not less than 40.0% and not more than 45.0% of MgO
<i>Description</i>	Light, white friable mass or bulky white powder
<i>Functional uses</i>	Anticaking agent

Item B.2. Petitioner and Manufacturer Information

<i>Petitioner</i>	LEROUX 84 rue François Herbo 59310 ORCHIES (France) Phone : 0033 3 20 64 48 00
<i>Manufacturer of magnesium hydroxide carbonate</i>	Dr. Paul Lohmann France SARL Boulevard de l'Yerres 52 91000 Évry (FRANCE) Phone : 0033 1 81 07 24 40

Item B.3. Intended or Current Use

	Use as a processing aid in the manufacture of organic instant chicory
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Item B.4. Intended Activities and Application Rate

<p>Magnesium hydroxide carbonate is a basic hydrated magnesium carbonate or a normal hydrated magnesium carbonate. It occurs as light, white, friable masses, or as a bulky, white powder. It is odorless, and is stable in air. It is practically insoluble in water, to which, however, it imparts a slightly alkaline reaction. It is insoluble in alcohol, but is dissolved by dilute acids with effervescence.</p> <p>Magnesium hydroxide carbonate is a GRAS substance under the provisions of the Code of Federal Regulations as miscellaneous and/or general purpose food additives.</p> <p>As a general purpose food additive, magnesium hydroxide carbonate is used as alkali in adjusting the acidity of foods.</p> <p>Magnesium hydroxide carbonate serves as an anticaking agent and carrier for other additives. Other uses of magnesium salts include processing aids.</p> <p>Magnesium is an essential nutrient for plants and animals and is a natural constituent of fruits, vegetables, grain, meats and sea foods.</p>	
Producer/Supplier	Dr Paul Lohmann
Article	Magnesium carbonate hydroxide
CAS No.	12125-28-9
Chemical composition	Mg(OH) ₂ CO ₃
Molecular weight	485 g/mol
Appearance	white powder
Mode of action	anticaking agent
Modalities and doses of use	The use of magnesium hydroxide carbonate as a processing aid is intended for the manufacture of instant chicory extract obtained by atomization. The incorporation of the E504(ii) is done in the air ring at the bottom of the tower feeding the dryer in order to obtain a re-aeration and a very good homogeneity of the product. The maximum quantity used would be 0.05%.
Basic topological data (ADI level)	ADI level; Not applicable E504 (ii): An ADI 'not specified' was established at the 23rd JECFA (1979)
Date of JECFA /SCF evaluation	E504 (ii): Prepared at the 27th JECFA (1983), published in FNP 28 (1983) and in FNP 52 (1992). Metals and arsenic specifications revised at the 59rd JECFA (2002) Refer to Appendix 1
Short summary	Magnesium is an alkali metal.

Item B.5. Manufacturing Process

Active ingredients:	Magnesium hydroxide carbonate
Possible carriers	Not applicable
Origin of raw materials (including aspects of mining/harvesting them), production methods	Magnesium is an alkali metal, it is the eighth most common element in the earth's crust. Pure magnesium reacts strongly in air or in association with other elements and is therefore mainly available in nature in ionized form such as carbonate for example. E504(ii) is of inorganic nature.

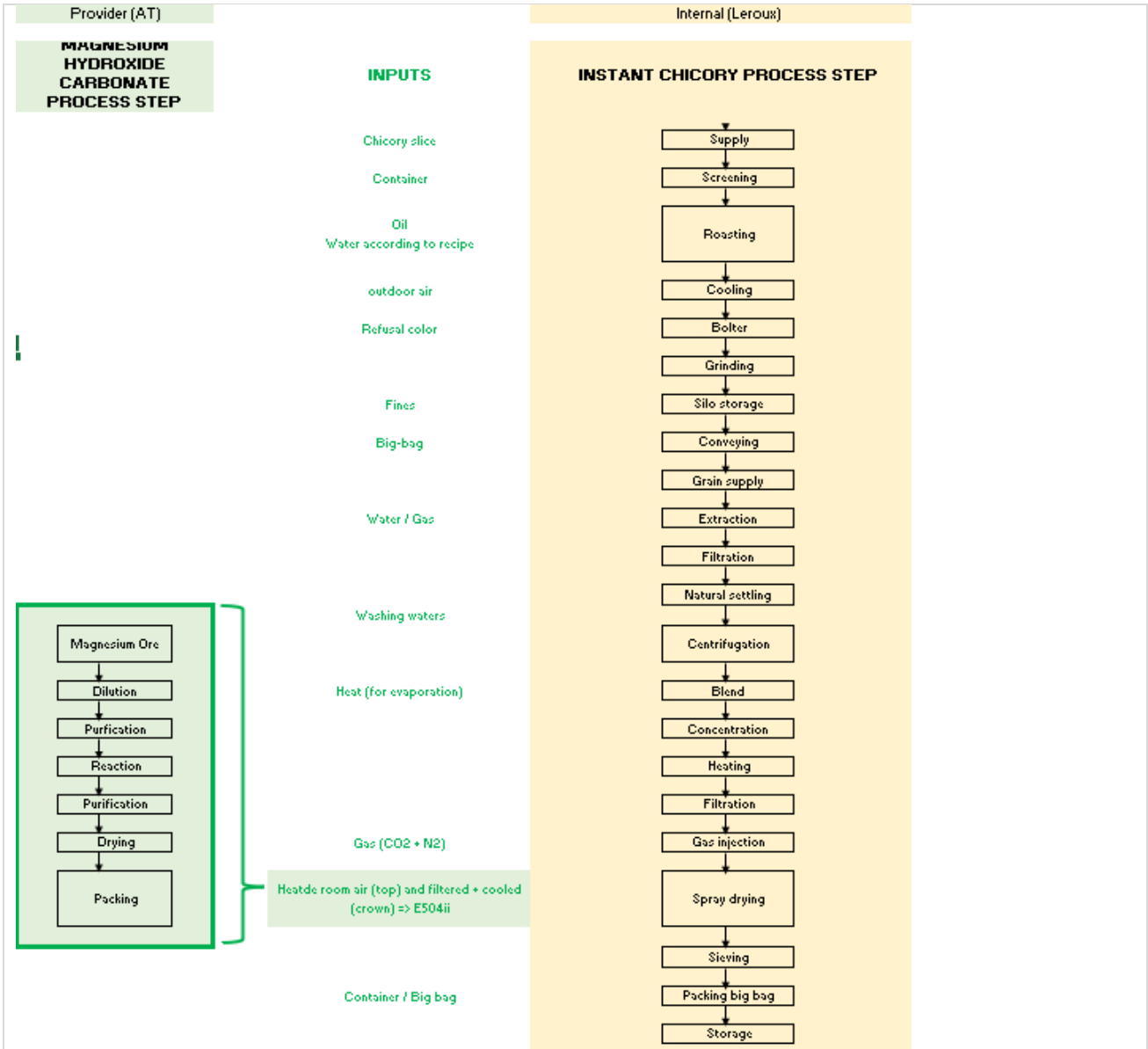
<i>Source of the substance</i>	Mineral
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The diagram of the production of Magnesium hydroxide carbonate is as follows:

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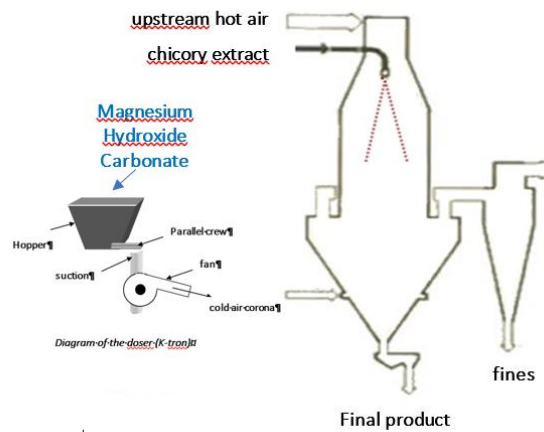
graph TD
  A[Magnesium Ore] --> B[Dilution]
  B --> C[Purification]
  C --> D[Reaction]
  D --> E[Purification]
  E --> F[Drying]
  F --> G[Packing]
  
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<i>Application during food processing</i>	E504(ii) is used during processing of liquid chicory into soluble powder
<i>Intended use</i>	The use of E504(ii) as a processing aid in the production of soluble chicory extract improves the fluidity and therefore the flow of the powder
<i>Technological function in food</i>	E504(ii) is used as a processing aid : anti-caking agent
<i>Technology</i>	The use of magnesium hydroxide carbonate as a processing aid is intended for the manufacture of the instant extract of chicory obtained by atomization. The incorporation of E504(ii) is done in the crown of air at the bottom of the tower feeding the dryer in order to obtain re-aeration and very good homogeneity of the product (figures 1 and 2). The maximum amount used would be 0.05%.
<i>Instant chicory flow chart</i>	



Instant chicory process

Schematic of a Tall form (Niro) atomizing tower



Item B.6. Ancillary Substances

	Not applicable
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Item B.7. Previous Reviews

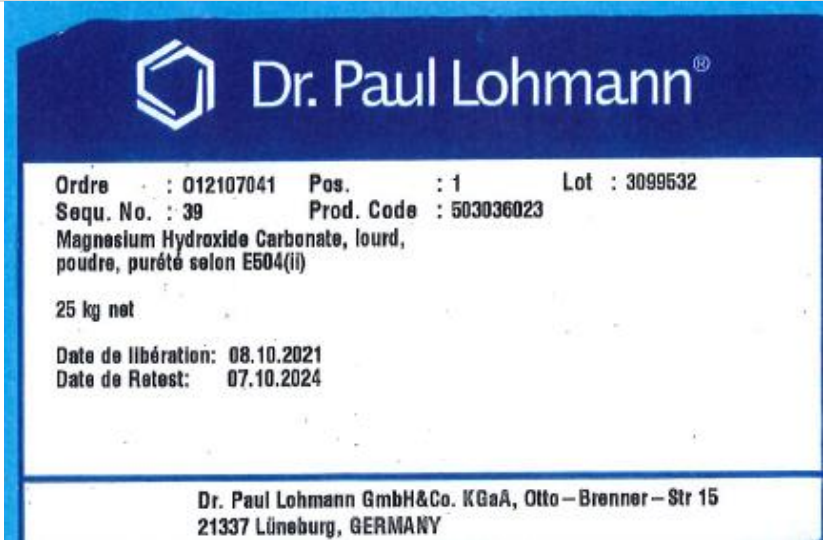
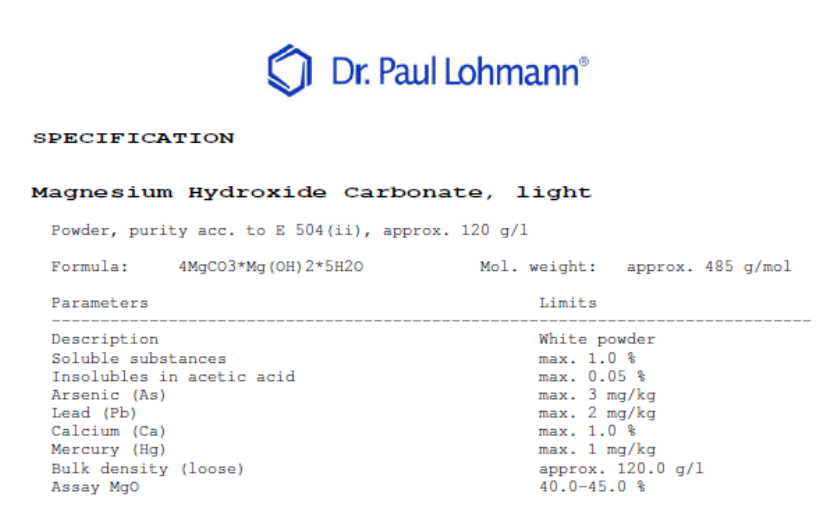
	<p>[Code of Federal Regulations] [Title 21, Volume 6] [CITE: 21CFR582.1428]</p>
<i>NOSB Review Documents</i>	<p>Scope = organic livestock production <i>“Magnesium carbonate is also known as magnesium carbonate hydroxide”</i> → following FDA source :</p> <p>[Code of Federal Regulations] [Title 21, Volume 3] [CITE: 21CFR184.1425]</p> <p style="text-align: center;">TITLE 21--FOOD AND DRUGS CHAPTER I--FOOD AND DRUG ADMINISTRATION DEPARTMENT OF HEALTH AND HUMAN SERVICES SUBCHAPTER B - FOOD FOR HUMAN CONSUMPTION (CONTINUED)</p> <p>PART 184 -- DIRECT FOOD SUBSTANCES AFFIRMED AS GENERALLY RECOGNIZED AS SAFE Subpart B - Listing of Specific Substances Affirmed as GRAS</p> <p>Sec. 184.1425 Magnesium carbonate.</p> <p>(a) Magnesium carbonate (molecular formula approximately $(MgCO_3)_4 \cdot Mg(OH)_2 \cdot 5H_2O$, CAS Reg. No. 39409-82-0) is also known as magnesium carbonate hydroxide. It is a white powder formed either by adding an alkaline carbonate (such as sodium carbonate) to a solution of magnesium sulfate or by carbonation of a slurry of magnesium hydroxide followed by boiling of the resulting magnesium carbonate.</p> <p>NOSB Review Documents</p> <ul style="list-style-type: none"> • 1996 NOSB review for addition to §205.605 for use as a processing aid • 1996 Technical Advisory Panel (pdf) • September 1996 NOSB Recommendation (pdf) (page 392) (synthetic, nonsynthetic) • November 2005 Petition (pdf) requesting addition to §205.605 for use as a processing aid (filtering aid) • October 2015 NOSB Subcommittee Proposal (pdf) (page 20) • October 2015 NOSB Recommendation (pdf) (page 27) <p style="text-align: center;">Sunset 2017 NOSB Final Review Handling Substances §205.605(a) October 2015</p> <p>As part of the National List Sunset Review process, the NOSB has evaluated the need for the continued allowance for or prohibition of the following substances for use in organic handling.</p> <p>Reference: 7 CFR 205.605 <i>Nonagricultural</i> (Nonorganic) substances allowed as ingredients in or on processed products labeled as “organic” or “made with organic (specified ingredients or food group(s)).”</p> <p>Magnesium Carbonate</p> <p>Reference: 205.605(b) - for use only in agricultural products labeled “made with organic (specified ingredients or food group(s)),” prohibited in agricultural products labeled “organic.”</p> <p>Technical Report: 1996 TAP</p> <p>Petition(s): Magnesium Carbonate (2005)</p> <p>Past NOSB Actions: 09/1996 NOSB minutes and vote; 11/2005 sunset recommendation; 10/2010 sunset recommendation</p> <p>Recent Regulatory Background: Sunset renewal notice published 06/06/12 (77 FR 33290)</p> <p>Sunset Date: 06/27/2017</p> <p>Subcommittee Review</p> <p>NOSB Review: The NOSB completed the sunset review for this material. Based on the Subcommittee review and public comment, the NOSB finds this material is no longer necessary for organic production and therefore no longer meets OFPA criteria. The NOSB recommends removal from the National List.</p> <p>Vote Motion to remove magnesium carbonate from 205.605(b) Motion by: Jean Richardson Seconded by: Harold Austin Yes: 14 No: 0 Abstain: 0 Absent: 0 Recuse: 0</p> <p>Outcome: Motion passed. NOSB completed its sunset review and recommended removal of Magnesium Carbonate.</p>

	<p>Rulemaking</p> <ul style="list-style-type: none"> Added to the National List, §205.605(b), effective April 21, 2001 (65 FR 80547, 66 FR 15619) Removed from the National List, effective August 07, 2017 (82 FR 31241)
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Item B.8. Regulatory Authority

	<p>[Code of Federal Regulations] [Title 21, Volume 6] [CITE: 21CFR582.1428]</p> <p style="text-align: center;">TITLE 21--FOOD AND DRUGS CHAPTER I--FOOD AND DRUG ADMINISTRATION DEPARTMENT OF HEALTH AND HUMAN SERVICES SUBCHAPTER E - ANIMAL DRUGS, FEEDS, AND RELATED PRODUCTS</p> <p>PART 582 -- SUBSTANCES GENERALLY RECOGNIZED AS SAFE Subpart B - General Purpose Food Additives</p> <p>Sec. 582.1428 Magnesium hydroxide.</p> <p>(a) <i>Product.</i> Magnesium hydroxide.</p> <p>(b) <i>Conditions of use.</i> This substance is generally recognized as safe when used in accordance with good manufacturing or feeding practice.</p> <p>[Code of Federal Regulations] [Title 21, Volume 3] [CITE: 21CFR184.1425]</p> <p style="text-align: center;">TITLE 21--FOOD AND DRUGS CHAPTER I--FOOD AND DRUG ADMINISTRATION DEPARTMENT OF HEALTH AND HUMAN SERVICES SUBCHAPTER B - FOOD FOR HUMAN CONSUMPTION (CONTINUED)</p> <p>PART 184 -- DIRECT FOOD SUBSTANCES AFFIRMED AS GENERALLY RECOGNIZED AS SAFE Subpart B - Listing of Specific Substances Affirmed as GRAS</p> <p>Sec. 184.1425 Magnesium carbonate.</p> <p>(a) Magnesium carbonate (molecular formula approximately $MgCO_3 \cdot 4Mg(OH)_2 \cdot 5H_2O$, CAS Reg. No. 39409-82-0) is also known as magnesium carbonate hydroxide. It is a white powder formed either by adding an alkaline carbonate (such as sodium carbonate) to a solution of magnesium sulfate or by carbonation of a slurry of magnesium hydroxide followed by boiling of the resulting magnesium carbonate.</p> <p>(b) The ingredient meets the specifications of the Food Chemicals Codex, 3d Ed. (1981), p. 177, which is incorporated by reference. Copies are available from the National Academy Press, 2101 Constitution Ave. NW., Washington, DC 20418, or available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to: http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.</p> <p>(c) In accordance with § 184.1(b)(1), the ingredient is used in food with no limitation other than current good manufacturing practice. The affirmation of this ingredient as generally recognized as safe (GRAS) as a direct human food ingredient is based upon the following current good manufacturing practice conditions of use:</p> <p>(1) The ingredient is used as an anticaking and free-flow agent as defined in § 170.3(o)(1) of this chapter; a flour treating agent as defined in § 170.3(o)(13) of this chapter; a lubricant and release agent as defined in § 170.3(o)(18) of this chapter; a nutrient supplement as defined in § 170.3(o)(20) of this chapter; a pH control agent as defined in § 170.3(o)(23) of this chapter; a processing aid as defined in § 170.3(o)(24) of this chapter; and a synergist as defined in § 170.3(o)(31) of this chapter.</p> <p>(2) The ingredient is used in foods at levels not to exceed current good manufacturing practice.</p> <p>(d) Prior sanctions for this ingredient different from the uses established in this section do not exist or have been waived.</p> <p>[50 FR 13558, Apr. 5, 1985; 50 FR 16080, Apr. 24, 1985]</p>
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Item B.9. Chemical Abstracts Service (CAS) Number and Product Labels

<i>Chemical names</i>	Magnesium hydroxide carbonate																				
<i>Synonyms</i>	INS No. 504(ii)																				
<i>C.A.S. number</i>	12125-28-9																				
<i>Product Label</i>	 <p>Dr. Paul Lohmann[®]</p> <p>Ordre : 012107041 Pos. : 1 Lot : 3099532 Sequ. No. : 39 Prod. Code : 503036023 Magnesium Hydroxide Carbonate, lourd, poudre, purété selon E504(ii)</p> <p>25 kg net</p> <p>Date de libération: 08.10.2021 Date de Retest: 07.10.2024</p> <p>Dr. Paul Lohmann GmbH&Co. KGaA, Otto-Brenner-Str 15 21337 Lüneburg, GERMANY</p>																				
<i>Product Specification</i>	 <p>Dr. Paul Lohmann[®]</p> <p>SPECIFICATION</p> <p>Magnesium Hydroxide Carbonate, light</p> <p>Powder, purity acc. to E 504(ii), approx. 120 g/l</p> <p>Formula: $4\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 5\text{H}_2\text{O}$ Mol. weight: approx. 485 g/mol</p> <table border="1"> <thead> <tr> <th>Parameters</th> <th>Limits</th> </tr> </thead> <tbody> <tr> <td>Description</td> <td>White powder</td> </tr> <tr> <td>Soluble substances</td> <td>max. 1.0 %</td> </tr> <tr> <td>Insolubles in acetic acid</td> <td>max. 0.05 %</td> </tr> <tr> <td>Arsenic (As)</td> <td>max. 3 mg/kg</td> </tr> <tr> <td>Lead (Pb)</td> <td>max. 2 mg/kg</td> </tr> <tr> <td>Calcium (Ca)</td> <td>max. 1.0 %</td> </tr> <tr> <td>Mercury (Hg)</td> <td>max. 1 mg/kg</td> </tr> <tr> <td>Bulk density (loose)</td> <td>approx. 120.0 g/l</td> </tr> <tr> <td>Assay MgO</td> <td>40.0-45.0 %</td> </tr> </tbody> </table>	Parameters	Limits	Description	White powder	Soluble substances	max. 1.0 %	Insolubles in acetic acid	max. 0.05 %	Arsenic (As)	max. 3 mg/kg	Lead (Pb)	max. 2 mg/kg	Calcium (Ca)	max. 1.0 %	Mercury (Hg)	max. 1 mg/kg	Bulk density (loose)	approx. 120.0 g/l	Assay MgO	40.0-45.0 %
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Item B.10. Physical and Chemical Properties

	Solubility; Practically insoluble in water; Insoluble in ethanol																					
<i>Other chemical interactions with other substances, besides solubility, if any, especially substances used in organic production</i>	Not applicable																					
<i>Toxicity and environmental persistence</i>	Not applicable																					
<i>Environmental impacts from its use and/or manufacture</i> https://echa.europa.eu/fr/registration-dossier/-/registered-dossier/23317/3/1/6	Magnesium carbonate hydroxide Hydrolysis : the study does not need to be conducted because the substance is inorganic Biodegradation in water : the study does not need to be conducted because the substance is inorganic Adsorption / desorption : the study does not need to be conducted because the physicochemical properties of the substance indicate that it can be expected to have a low potential for adsorption																					
<i>Environmental impacts during processing</i>	We would like to include Magnesium hydroxide carbonate in the list of substances authorized as a processing aid. We will not use Magnesium hydroxide carbonate in the chicory root cultivation phases but only during factory processing. The use of E504(ii) as a processing aid in the production of instant chicory extract improves the fluidity and therefore the flow of the powder. Favored flow generates a reduction in fouling in production and packaging facilities and consequently production compatible with industrial expectations (reduction of material losses and rationalization of cleaning and the associated quantity of water). The environmental impact can be approximated on the basis of the data shown in the table below: Comparative production data with or without processing aid :																					
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<i>Effects on Human health</i>	Not applicable																					
<i>Effects on soil organisms, crops, or livestock</i>	Not applicable																					
<i>Food quality and authenticity</i>	Not applicable																					

Item B.11. Safety Information

Page 1/7

Safety data sheet
 according to 1907/2006/EC, Article 31

Printing date 07.10.2022

Version number 7.00

Revision: 24.08.2022

SECTION 1: Identification of the substance/mixture and of the company/undertaking

- **1.1 Product identifier**
- Trade name: Magnesium carbonate
- Article number: C36
- CAS Number: 12125-28-9
- EC number: 235-192-7
- Registration number
 For traceability reasons, you will receive info on the REACH registration number upon request. If you have a use subject to registration under REACH, please contact our sales department.
- **1.2 Relevant identified uses of the substance or mixture and uses advised against**
 No further relevant information available.
- **Application of the substance / the mixture**
 Food additive
 Coating
 Pharma Active ingredients
- **1.3 Details of the supplier of the safety data sheet**
- **Manufacturer/Supplier:**
 Dr. Paul Lohmann GmbH & Co. KGaA
 Hauptstraße 2
 D-31860 Emmerthal
 GERMANY
 MSDS@lohmann-chemikalien.de
- **Further information obtainable from:** Product safety department
- **1.4 Emergency telephone number:**
 Emergency CONTACT (24-Hour-Number): GBK GmbH +49 (0)6132-84463

SECTION 2: Hazards identification

- **2.1 Classification of the substance or mixture**
- Classification according to Regulation (EC) No 1272/2008
 The substance is not classified, according to the CLP regulation.
- **2.2 Label elements**
- Labelling according to Regulation (EC) No 1272/2008 Void
- Hazard pictograms Void
- Signal word Void
- Hazard statements Void
- **2.3 Other hazards**
- Results of PBT and vPvB assessment
- PBT: Not applicable.
- vPvB: Not applicable.

SECTION 3: Composition/information on ingredients

- **3.1 Chemical characterisation: Substances**
- CAS No. Description
 12125-28-9 Magnesium carbonate
 Alternative CAS number: 39409-82-0
- Identification number(s)
- EC number: 235-192-7

SECTION 4: First aid measures

- **4.1 Description of first aid measures**
- **General information:** Immediately remove any clothing soiled by the product.

(Contd. on page 2)

EU

Safety data sheet
 according to 1907/2006/EC, Article 31

Printing date 07.10.2022

Version number 7.00

Revision: 24.08.2022

Trade name: Magnesium carbonate

(Contd. of page 1)

- **After inhalation:** Supply fresh air; consult doctor in case of complaints.
- **After skin contact:** If skin irritation continues, consult a doctor.
- **After eye contact:**
 Rinse opened eye for several minutes under running water. If symptoms persist, consult a doctor.
- **After swallowing:**
 Rinse out mouth and then drink plenty of water.
 If symptoms persist consult doctor.
- **4.2 Most important symptoms and effects, both acute and delayed** No further relevant information available.
- **4.3 Indication of any immediate medical attention and special treatment needed**
 No further relevant information available.

SECTION 5: Firefighting measures

- **5.1 Extinguishing media**
- **Suitable extinguishing agents:** Use fire extinguishing methods suitable to surrounding conditions.
- **5.2 Special hazards arising from the substance or mixture**
 In case of fire, the following can be released:
 Carbon monoxide and carbon dioxide
- **5.3 Advice for firefighters**
- **Protective equipment:**
 Do not inhale explosion gases or combustion gases.
 Wear self-contained respiratory protective device.

SECTION 6: Accidental release measures

- **6.1 Personal precautions, protective equipment and emergency procedures**
 Avoid formation of dust.
 Wear protective clothing.
- **6.2 Environmental precautions:** Do not allow to enter sewers/ surface or ground water.
- **6.3 Methods and material for containment and cleaning up:**
 Pick up mechanically.
 Send for recovery or disposal in suitable receptacles.
- **6.4 Reference to other sections**
 See Section 7 for information on safe handling.
 See Section 8 for information on personal protection equipment.
 See Section 13 for disposal information.

SECTION 7: Handling and storage

- **7.1 Precautions for safe handling**
 Prevent formation of dust.
 Thorough dedusting.
- **Information about fire - and explosion protection:** The product is not flammable.
- **7.2 Conditions for safe storage, including any incompatibilities**
- **Storage:**
Requirements to be met by storerooms and receptacles: No special requirements.
Information about storage in one common storage facility: Not required.
Further information about storage conditions: Store in cool, dry conditions in well sealed receptacles.
- **7.3 Specific end use(s)** No further relevant information available.

SECTION 8: Exposure controls/personal protection

- **8.1 Control parameters**
- **Additional information about design of technical facilities:** No further data; see item 7.

(Contd. on page 3)

III

Safety data sheet
 according to 1907/2006/EC, Article 31

Printing date 07.10.2022

Version number 7.00

Revision: 24.08.2022

Trade name: Magnesium carbonate

(Contd. of page 2)

- **Ingredients with limit values that require monitoring at the workplace:** Not required.
- **Additional information:** The lists valid during the making were used as basis.
- **8.2 Exposure controls**
- **Personal protective equipment:**
- **General protective and hygienic measures:**
 The usual precautionary measures are to be adhered to when handling chemicals.
 Keep away from foodstuffs, beverages and feed.
 Do not eat, drink, smoke or sniff while working.
 Be sure to clean skin thoroughly after work and before breaks.
- **Respiratory protection:** Use suitable respiratory protective device in case of insufficient ventilation.
- **Protection of hands:**



Protective gloves

The glove material has to be impermeable and resistant to the product/ the substance/ the preparation.
 Due to missing tests no recommendation to the glove material can be given for the product/ the preparation/ the chemical mixture.

Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation

- **Material of gloves**
 The selection of the suitable gloves does not only depend on the material, but also on further marks of quality and varies from manufacturer to manufacturer.
- **Penetration time of glove material**
 The exact break through time has to be found out by the manufacturer of the protective gloves and has to be observed.
- **Eye protection:** Safety glasses
- **Body protection:** Protective work clothing

SECTION 9: Physical and chemical properties

- **9.1 Information on basic physical and chemical properties**
- **General Information**
- **Appearance:**

Form:	Powder
Colour:	White
Odour:	Nearly odourless
Odour threshold:	Not determined.
- **pH-value (50 g/l) at 20 °C:** 10-11
- **Change in condition**

Melting point/freezing point:	Undetermined.
Initial boiling point and boiling range:	Undetermined.
- **Flash point:** Not applicable.
- **Flammability (solid, gas):** Product is not flammable.
- **Ignition temperature:** Not determined.
- **Decomposition temperature:** Not determined.
- **Auto-ignition temperature:** Not determined.
- **Explosive properties:** Product does not present an explosion hazard.
- **Explosion limits:**

Lower:	Not determined.
Upper:	Not determined.

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Trade name: Magnesium carbonate

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- Vapour pressure:	Not applicable.
- Density:	Not determined.
- Relative density	Not determined.
- Vapour density	Not applicable.
- Evaporation rate	Not applicable.
- Solubility in / Miscibility with water:	Insoluble.
- Partition coefficient: n-octanol/water:	Not determined.
- Viscosity:	
Dynamic:	Not applicable.
Kinematic:	Not applicable.
- 9.2 Other information	No further relevant information available.

SECTION 10: Stability and reactivity

- 10.1 Reactivity No further relevant information available.
- 10.2 Chemical stability
- Thermal decomposition / conditions to be avoided:
 To avoid thermal decomposition do not overheat.
 No decomposition if used and stored according to specifications.
- 10.3 Possibility of hazardous reactions Reacts with acids.
- 10.4 Conditions to avoid No further relevant information available.
- 10.5 Incompatible materials: No further relevant information available.
- 10.6 Hazardous decomposition products:
 In case of fire, the following can be released:
 Carbon monoxide and carbon dioxide

SECTION 11: Toxicological information

- 11.1 Information on toxicological effects
 - Acute toxicity Based on available data, the classification criteria are not met.
 - LD/LC50 values relevant for classification:
- | |
|--|
| Oral LD50 > 2,000 mg/kg (rat) (OECD Guideline 420) |
|--|
- Primary irritant effect:
 - Skin corrosion/irritation Based on available data, the classification criteria are not met.
 - Serious eye damage/irritation Based on available data, the classification criteria are not met.
 - Respiratory or skin sensitisation Based on available data, the classification criteria are not met.
 - Additional toxicological information:
 - Toxicokinetics, metabolism and distribution Undetermined.
 - Acute effects (acute toxicity, irritation and corrosivity) Undetermined.
 - Sensitisation Undetermined.
 - Repeated dose toxicity Undetermined.
 - CMR effects (carcinogenicity, mutagenicity and toxicity for reproduction)
 - Germ cell mutagenicity Based on available data, the classification criteria are not met.
 - Carcinogenicity Based on available data, the classification criteria are not met.
 - Reproductive toxicity Based on available data, the classification criteria are not met.
 - STOT-single exposure Based on available data, the classification criteria are not met.
 - STOT-repeated exposure Based on available data, the classification criteria are not met.
 - Aspiration hazard Based on available data, the classification criteria are not met.

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Trade name: Magnesium carbonate

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- 11.2 Information on other hazards
- Endocrine disrupting properties Substance is not listed.

SECTION 12: Ecological information

- 12.1 Toxicity
- Aquatic toxicity: No further relevant information available.
- 12.2 Persistence and degradability No further relevant information available.
- 12.3 Bioaccumulative potential No further relevant information available.
- 12.4 Mobility in soil No further relevant information available.
- Additional ecological information:
- General notes:
 Water hazard class 1 (German Regulation) (Self-assessment): slightly hazardous for water
 Do not allow undiluted product or large quantities of it to reach ground water, water course or sewage system.
- 12.5 Results of PBT and vPvB assessment
- PBT: Not applicable.
- vPvB: Not applicable.
- 12.6 Other adverse effects No further relevant information available.

SECTION 13: Disposal considerations

- 13.1 Waste treatment methods
- Recommendation Smaller quantities can be disposed of with household waste.
- Uncleaned packaging:
- Recommendation: Disposal must be made according to official regulations.

SECTION 14: Transport information

- | | |
|---|--|
| - 14.1 UN-Number | Void |
| - ADR, ADN, IMDG, IATA | Void |
| - 14.2 UN proper shipping name | Void |
| - ADR, ADN, IMDG, IATA | Void |
| - 14.3 Transport hazard class(es) | Void |
| - ADR, ADN, IMDG, IATA | Void |
| - Class | Void |
| - 14.4 Packing group | Void |
| - ADR, IMDG, IATA | Void |
| - 14.5 Environmental hazards: | No |
| - Marine pollutant: | No |
| - 14.6 Special precautions for user | Not applicable. |
| - 14.7 Transport in bulk according to Annex II of Marpol and the IBC Code | Not applicable. |
| - Transport/Additional information: | Not dangerous according to the above specifications. |
| - UN "Model Regulation": | Void |

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SECTION 15: Regulatory information

- **15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture**
 No further relevant information available.
- **TSCA (Toxic Substances Control Act):** Substance is not listed.
- **TSCA new (21st Century Act)** Substance is not listed.
- **Canadian, Domestic Substances List (DSL)** Substance is not listed.
- **Philippines Inventory of Chemicals and Chemical Substances** Substance is listed.
- **Chinese Chemical Inventory of Existing Chemical Substances** Substance is listed.
- **Australian Inventory of Industrial Chemicals** Substance is listed.
- **Korean Existing Chemical Inventory KE-22687**
- **New Zealand Inventory of Chemicals** Substance is listed.
- **HSNO Approval numbers** Substance is not listed.
- **TCSI - Taiwan Chemical Substance Inventory** Substance is listed.

- **Japanese Existing Chemical Substances**

12125-28-9	Magnesium carbonate
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- **Directive 2012/18/EU**
- **Regulation (EU) No 649/2012** Substance is not listed.
- **DIRECTIVE 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment – Annex II**
 Substance is not listed.
- **REGULATION (EU) 2019/1148**
- **Annex I - RESTRICTED EXPLOSIVES PRECURSORS (Upper limit value for the purpose of licensing under Article 5(3))**
 Substance is not listed.
- **Annex II - REPORTABLE EXPLOSIVES PRECURSORS** Substance is not listed.
- **Regulation (EC) No 273/2004 on drug precursors** Substance is not listed.
- **Regulation (EC) No 111/2005 laying down rules for the monitoring of trade between the Community and third countries in drug precursors**
 Substance is not listed.
- **EINECS** Substance is listed.
- **REACH - Pre-registered substances** Substance is listed.
- **15.2 Chemical safety assessment:** A Chemical Safety Assessment has not been carried out.

SECTION 16: Other information

This safety data sheet contains only safety-relevant information. The information is based on the state of our knowledge at the time of revision, but does not constitute an assurance of product properties, product information or product specifications and does not establish a contractual legal relationship. This document is only valid in its unchanged form. Dr. Paul Lohmann® accepts no responsibility for the form and content of any changes made by third parties, nor for any resulting damage or claims. The information is not transferable to other products. Insofar as the product named in this safety data sheet is mixed, blended, processed with or without other materials, the information in this safety data sheet cannot be transferred to the new material produced in this way, unless expressly stated otherwise. The data sheet does not release the user from the obligation to ensure that he acts in accordance with all regulations in connection with his activity.

- **Department issuing SDS:** Product safety department
- **Contact:**
- **Abbreviations and acronyms:**
 RID: Règlement international concernant le transport des marchandises dangereuses par chemin de fer (Regulations Concerning the International Transport of Dangerous Goods by Rail)
 ICAO: International Civil Aviation Organisation
 ADR: Accord relatif au transport international des marchandises dangereuses par route (European Agreement Concerning the International Carriage of Dangerous Goods by Road)
 IMDG: International Maritime Code for Dangerous Goods
 IATA: International Air Transport Association
 GHS: Globally Harmonised System of Classification and Labelling of Chemicals

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EINECS: European Inventory of Existing Commercial Chemical Substances
CAS: Chemical Abstracts Service (division of the American Chemical Society)
LC50: Lethal concentration, 50 percent
LD50: Lethal dose, 50 percent
PBT: Persistent, Bioaccumulative and Toxic
vPvB: very Persistent and very Bioaccumulative
- * Data compared to the previous version altered.

EU

Item B.11

<i>Substance report from the National Institute of Environmental Health Sciences</i>	
<ul style="list-style-type: none"> The National Institute of Environmental Health Sciences (NIEHS)/ The National Toxicology Program (NTP) https://www.niehs.nih.gov/ 	Information does not exist
<ul style="list-style-type: none"> The Agency for Toxic Substances and Disease Registry (ATSDR): https://www.atsdr.cdc.gov/ 	Non applicable
<ul style="list-style-type: none"> U.S. National Library of Medicine's PubChem database: https://pubchem.ncbi.nlm.nih.gov/ 	 <p>MAGNESIUM CARBONATE HYDROXIDE; 12125-28-9 Substance SID: 464862678 Compound CID: 3014667 Data Source: EPA Substance Registry Services External ID: 1977547 Data Source Category: Governmental Organizations Deposit Date: 2022-06-22 Last Modified Date: 2022-06-22</p>
<ul style="list-style-type: none"> The Occupational Safety and Health Administration (OSHA): https://www.osha.gov/ 	Information does not exist
<ul style="list-style-type: none"> The National Institute for Occupational Safety and Health (NIOSH): https://www.cdc.gov/niosh/index.htm 	Information does not exist
<ul style="list-style-type: none"> U.S. Environmental Protection Agency (U.S. EPA) 	Not applicable
<ul style="list-style-type: none"> U.S. Food and Drug Administration (FDA) 	CFR - Code of Federal Regulations Title 21 (fda.gov)
<p>"Magnesium carbonate is also know as magnesium carbonate hydroxide" → following FDA source :</p> <div style="border: 1px solid black; padding: 5px;"> <p>[Code of Federal Regulations] [Title 21, Volume 3] [CITE: 21CFR184.1425]</p> <p style="text-align: center;">TITLE 21--FOOD AND DRUGS CHAPTER I--FOOD AND DRUG ADMINISTRATION DEPARTMENT OF HEALTH AND HUMAN SERVICES SUBCHAPTER B - FOOD FOR HUMAN CONSUMPTION (CONTINUED)</p> <p>FART 184 -- DIRECT FOOD SUBSTANCES AFFIRMED AS GENERALLY RECOGNIZED AS SAFE Subpart B - Listing of Specific Substances Affirmed as GRAS</p> <p>Sec. 184.1425 Magnesium carbonate.</p> <p>(a) Magnesium carbonate (molecular formula approximately $MgCO_3 \cdot 4-Mg(OH)_2 \cdot 5H_2O$, CAS Reg. No. 39409-82-0) is also known as magnesium carbonate hydroxide. It is a white powder formed either by adding an alkaline carbonate (such as sodium carbonate) to a solution of magnesium sulfate or by carbonation of a slurry of magnesium hydroxide followed by boiling of the resulting magnesium carbonate.</p> </div>	
<p>Title 21 - Food and Drugs Chapter I - Food and Drug Administration, Department of Health and Human Services Subchapter E - Animal Drugs, Feeds, and Related Products Part 582 - Substances Generally Recognized as Safe Subpart B - General Purpose Food Additives</p> <p>§ 582.1428 Magnesium hydroxide.</p> <p>(a) Product. Magnesium hydroxide.</p> <p>(b) Conditions of use. This substance is generally recognized as safe when used in accordance with good manufacturing or feeding practice.</p>	

Item B.B.12

Substance research reviews and research bibliographies

Title : Analytical methods in food additives determination: Compounds with functional applications,
 Author : Fernanda C.O.L.Martins, Michelle A. Sentanin, Djenaine De Souza
 Journal : Food Chemistry, Volume 272, 30 January 2019, Pages 732-750
 Refer to Appendix 3

Item B.13

Substance is petitioned for §205.605(b) (nonagricultural, synthetic)

Why the synthetic substance is necessary for the production or handling of an organic product

Magnesium hydroxide carbonate is used during processing of liquid chicory into soluble powder. The use of Magnesium hydroxide carbonate as a processing aid in the production of instant chicory extract improves the fluidity and therefore the flow of the powder. Magnesium hydroxide carbonate is used as a processing aid: anti-caking agent.

Nonsynthetic substances, synthetic substances on the National List that could be used in place of the petitioned synthetic substance

[§ 205.605 Nonagricultural \(nonorganic\) substances allowed as ingredients in or on processed products labelled as “organic” or “made with organic \(specified ingredients or food group\(s\)\).”](#)
 The following nonagricultural substances may be used as ingredients in or on processed products labelled as “organic” or “made with organic (specified ingredients or food group(s))” only in accordance with any restrictions specified in this section.

(b) ***Synthetics allowed:***

[...] Silicon dioxide - Permitted as a defoamer. Allowed for other uses when organic rice hulls are not commercially available.



7 CFR 205.605 (up to date as of 8-26-2022)

Beneficial effects to the environment, human health, or farm ecosystem from use of the synthetic substance that support its use instead of the use of a nonsynthetic substance or alternative cultural method.

Non applicable
 Not used during crop fields but after harvest, during the chicory transformation process.
 We would like Magnesium hydroxide carbonate to be included in the list of substances authorized as a processing aid.
 We will not use Magnesium hydroxide carbonate in the chicory root cultivation phases but only during factory processing.

Appendix 1 : JECFA

MAGNESIUM HYDROXIDE CARBONATE

Prepared at the 27th JECFA (1983), published in FNP 28 (1983) and in FNP 52 (1992). Metals and arsenic specifications revised at the 59th JECFA (2002). An ADI 'not specified' was established at the 23rd JECFA (1979)

SYNONYMS	Magnesium subcarbonate (light or heavy), hydrated basic magnesium carbonate, magnesium carbonate hydroxide; INS No. 504(ii)
DEFINITION	
Chemical names	Magnesium carbonate hydroxide hydrated
Assay	Not less than 40.0% and not more than 45.0% of MgO
DESCRIPTION	Odourless, light, white, friable masses, or a bulky-white powder
FUNCTIONAL USES	Alkali, drying agent, colour-retention agent, carrier, anti-caking agent
CHARACTERISTICS	
IDENTIFICATION	
<u>Solubility</u> (Vol. 4)	Practically insoluble in water; insoluble in ethanol
<u>Alkalinity</u>	Slurry shows slight alkalinity
<u>Test for magnesium</u> (Vol. 4)	Passes test
PURITY	
<u>Soluble salts</u>	Not more than 1.0% Mix 2 g of the sample with 100 ml of a mixture of equal volumes of n-propanol and water. Heat the mixture to the boiling point with constant stirring, cool to room temperature, add water to make 100 ml and filter. Evaporate 50 ml of the filtrate on a steam bath to dryness, and dry at 105° for 1 h. The weight of the residue does not exceed 10 mg.
<u>Calcium</u>	Not more than 1.0% Dissolve about 1 g of the sample, accurately weighed, in a mixture of 3 ml of sulfuric acid and 22 ml of water. Add 50 ml of ethanol and allow the mixture to stand overnight. If crystals of magnesium sulfate separate, warm the mixture to about 50° to dissolve them. Filter through a Gooch crucible containing an asbestos mat that previously has been washed with dilute sulfuric acid TS, water, and ethanol, and ignited and weighed. Wash the crystals on the mat several times with a mixture of 2 volumes of ethanol and 1 volume of dilute sulfuric acid TS. Ignite the crucible and contents to a dull red heat, cool, and weigh. The weight of calcium sulfate so obtained, multiplied by 0.2944 gives the equivalent of calcium in the sample taken for the test.
<u>Acid insoluble matter</u>	Not more than 0.05% Mix 5 g of the sample with 75 ml of water, add hydrochloric acid in small portions, with agitation, until no more of the sample dissolves, and boil for 5 min. If an insoluble residue remains, filter, wash well with water until the last washing is free from chloride, ignite, cool and weigh.
<u>Lead</u> (Vol. 4)	Not more than 2 mg/kg Determine using an atomic absorption technique appropriate to the specified level. The selection of sample size and method of sample preparation may be based on the principles of the method described in Volume 4, "Instrumental Methods."
METHOD OF ASSAY	Dissolve about 1 g of the sample, accurately weighed, in 30 ml of 1 N sulfuric acid, add methyl orange TS, and titrate the excess acid with 1 N sodium hydroxide. From the volume of 1 N sulfuric acid consumed, deduct the volume of 1 N sulfuric acid corresponding to the content of calcium oxide in the weight of the sample taken for the assay. The difference is the volume of 1 N sulfuric acid equivalent to the magnesium oxide present. Each ml of 1 N sulfuric acid is equivalent to 20.15 mg of MgO.

Appendix 2 : NOBS “ Technical Advisory Panel (pdf)”

CFNP TAP Review
 10/12/2007

Magnesium Hydroxide

Executive Summary

Magnesium hydroxide was petitioned for use in organic livestock production. Magnesium itself does not occur naturally but in the form of the mineral brucite. Magnesium hydroxide is used as an antacid for temporary relief of an upset stomach and as a laxative for short-term relief of constipation. Magnesium hydroxide is also used as a flame retardant and smoke depressant. Organic farmers historically use Rumalax or Magnalax, for cattle, particularly, with digestive problems. Reusable solids (also called biosolids or sludge) are lime materials, particularly magnesium hydroxide, that are used as a cheap alternative to expensive chemical fertilizers.

The FDA first deemed magnesium hydroxide safe on April 5, 1985 (50 FR 13559). It was later amended on January 5, 1999 (64 FR 405). The Miscellaneous Food Additives Regulations, 1995, has deemed magnesium hydroxide suitable for general food use. The EPA has confirmed that magnesium hydroxide is not found in ground water supplies. Therefore, unless prodigious natural deposits of magnesium hydroxide are found in the actual soil, the exposure of such a compound will not be detrimental and will not affect systems of sustainable agriculture. Magnesium hydroxide and magnesium oxide are currently under review by the USDA. There is no official ruling at this time and are petitioned to be reviewed in September 2002.

The NOP says at section 205.238 that “the producer of an organic livestock operation must not: (2) administer any animal drug, other than vaccinations, in the absence of illness. Organic farmers are not allowed to give unnecessary medicines to livestock. As in section 205.600 of the NOP final rule, “any synthetic substance used as a processing aid or adjuvant will be evaluated against the following criteria: (2) the substance’s manufacture, used and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling.” Magnesium hydroxide/oxide is not explicitly listed in section 205.603 as a synthetic substance allowed for use in organic livestock production nor is it listed in section 205.604 as a prohibited substance.

Summary of TAP Reviewer’s Analyses¹

<i>Synthetic/ Nonsynthetic</i>	<i>Allow without restrictions?</i>	<i>Allow only with restrictions? (See Reviewers’ comments for restrictions)</i>
Synthetic(0) Nonsynthetic (3)	Yes (1) No (2)	Yes (2) No (1)

Identification

¹ This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the investigator’s ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(M) of the OFPA [7 USC 6517(m)]. The information and advice presented to the NOSB is based on the technical evaluation against that criteria, and does not incorporate commercial availability, socio-economic impact, or other factors that the NOSB and the USDA may want to consider in making decisions.

Chemical names:

Magnesium Oxide/Magnesium Hydroxide
Chemical formula: Mg(OH)₂-Magnesium Hydroxide
MgO- Magnesium Oxide
Molecular Weight: 58.32 (Magnesium Hydroxide)
40.32 (Magnesium Oxide)
CAS No: 1309-42-8 (Magnesium Hydroxide)
1309-48-4 (Magnesium Oxide)

Other Names:

Brucite, Nematite, Milk of magnesia (MOM), magnesium hydrate, antacid, Magnalax, Rumalax

Characterization

Composition:

Properties

Magnesium Hydroxide

Melting point: 350 °C
Density (g cm⁻³): 2.36
Water solubility: negligible
Color is white or colorless with shades of gray, blue and green.
Luster is vitreous or waxy; cleavage surfaces have a pearly luster.
Transparency Crystals are translucent and rarely transparent.
Crystal System is trigonal; bar 3 2/m
Crystal Habit is typically in flattened tabular crystals with rare rhombohedral terminations. Also found in lamellar and fibrous aggregates and as foliated masses.
Cleavage is perfect in one direction, basal.
Fracture is uneven.
Hardness is 2 - 2.5
Specific Gravity is 2.4 (slightly below average)
Streak is white.
Other Characteristics: cleavage flakes and fibers are flexible but not elastic.²

Magnesium Oxide

Appearance: Bulky white powder.
Odor: Odorless.
Solubility: Insoluble in water.
Specific Gravity: 3.58 @ 25C (77F)
pH: 10.3
% Volatiles by volume @ 21C (70F): 0
Boiling Point: 3600C (6512F)
Melting Point: 2800C (5072F)
Vapor Density (Air=1): No information found.
Vapor Pressure (mm Hg): No information found.

² Information was referenced from http://physchem.ox.ac.uk/MSDS/MA/magnesium_hydroxide.htm

Evaporation Rate (BuAc=1):

No information found.

Color is colorless, white, gray, yellow to brown or black

Luster is vitreous to adamantine.

Transparency crystals are transparent to translucent.

Crystal System is isometric; 4/m bar 3 2/m

Crystal Habits include the typical cubes and octahedrons as well as rounded indistinct grains.

Cleavage is perfect in three directions forming cubes.

Hardness is 5.5

Specific Gravity is 3.6 (slightly above average)

Streak is white.

Other Characteristics: Crystals may dull in humid air³

How Made:

Magnesium hydroxide (Brucite) is found naturally in serpentine, chlorite or dolomitic schists, or in crystalline limestones as an alteration product of periclase (magnesium oxide). It is prepared by mixing sodium hydroxide with a water-soluble magnesium salt. It is also formed by the hydration of reactive magnesium oxide. Either case produces a white precipitate.⁴ Four companies in California, Delaware, and Florida, three companies in Michigan, and two companies in Utah recovered magnesium oxide and similar compounds from seawater. Seawater extraction and natural brines account for 70% of the U.S. magnesium production. Worldwide, there are several million tons of brucite resources.⁵

Specific Uses:

Magnesium hydroxide is used as an antacid for temporary relief of an upset stomach and as a laxative for short-term relief of constipation. Magnesium hydroxide is used as a flame retardant and smoke depressant for temperatures exceeding 400 degrees Fahrenheit. Magnesium hydroxide is also a general food additive used as a color-retention agent, drying agent, pH control agent, or processing aid. Magnesium hydroxide is also used as a fertilizer (in the form of lime) as a substitute for more expensive chemical fertilizers.

Non-hazardous for air, sea and road freight

Avoid contact with the eyes

May cause slight skin irritation

Action:

Magnesium hydroxide is mainly used in antacid or laxative tablets. Antacid tablets are used to relieve minor stomach pain caused by indigestion. Antacids are taken orally to relieve heartburn, acid indigestion, and hyperacidity. Antacids are occasionally taken with simethicone, which may relieve the symptoms of flatulence. Antacids taken alone or in conjunction with simethicone can also help relieve stomach or duodenal ulcers. A laxative effect will occur with greater doses of magnesium hydroxide, those exceeding doses for an antacid effect. Magnesium hydroxide is given orally as gel, tablets or syrup. Aluminum Hydroxide tab 0.84 gm; suspension 0.6g/10ml give sixth to eighth hourly. Magnesium Hydroxide suspension; 0.4 gm / 5 ml given every 6 to 8 hrs. Antacids do have the potential of causing problems during pregnancy. Sodium filled antacids have been linked with edema. Those on special low sodium diets should

³ Information was referenced from <http://mineral.galleries.com/minerals/oxides/periclas/periclas.htm>

⁴ Information was referenced from <http://mineral.galleries.com/minerals/oxides/brucite/brucite.htm>

⁵ Information was referenced from <http://minerals.usgs.gov/minerals/pubs/commodity/magnesium/401300.pdf>

take extra precautions because some antacids may have very high sodium contents. Antacids have also been linked to renal disease due to the high serum levels of aluminum, calcium, or magnesium caused by extensive use. It is possible for persons to experience allergic reactions to antacids. Antacids should not be used in small children nor should they be used extensively by expecting mothers. It is possible for aluminum, calcium or magnesium to be carried to the baby through breast milk. Those experiencing renal disease, persons with bone disorders, or Alzheimer's disease, should not use aluminum containing antacids.⁶ Magnesium hydroxide, or better known by farmers as Rumalax or Magnalax, is used for livestock with digestive problems. Dosage size of Rumalax should be administered based upon animal condition and size. The normal dosage is anywhere from two to four boluses. Humans consume antacids orally just as Rumalax is administered orally to cattle. A lubricant of some kind should be used before administering this drug to cattle or other such livestock.⁷

Note- Three boluses are equivalent to about one quart of Milk of Magnesia.

Combinations:

Combination drugs of magnesium hydroxide include: 1) calcium rich Roloids, 2) Di-Gel tablets, 3) Maalox, 4) Mylanta, and 5) Tempo tablets. Magnesium hydroxide may reduce absorption of dietary iron. Those with potassium deficiency problems or those with potential deficiency problems may experience low serum potassium levels in the body if taking magnesium hydroxide. In this case, potassium supplements should be taken while consuming antacids. Antacids have various drug interactions. They may reduce the potency of Fluoroquinolones and Cellulose Sodium Phosphate. Magnesium antacids may prevent either drug from acting effectively. Antacids should not be taken within one hour of taking Cellulose Sodium Phosphate. Aluminum containing antacids may react with Isoniazid and should not be taken within one hour of consumption. Antacids may decrease the effects of ketoconazole or methenamine; therefore these drugs should be taken 3 hours before antacid consumption. Antacids should not be taken within three or four hours of tetracyclines (consumed orally as well).⁸ There are no known food interactions with magnesium hydroxide or more commonly with MOM. One should not use antacids or laxatives if they are experiencing lower abdominal pains or appendicitis. Persons with liver or kidney disease, bone disorders, hemorrhoids or intestinal bleeding, and expecting women should consult a doctor before taking either antacids or laxatives.

Status

Historic Use by Organic Farmers:

Organic farmers historically use Rumalax or Magnalax, for cattle, particularly, with digestive problems. Reusable solids (also called biosolids or sludge) are lime materials, particularly magnesium hydroxide, that are used as a cheap alternative to expensive chemical fertilizers. Farmers use biosolids to improve soil and crop quality. These biosolids are made with alkaline chemicals including potassium, calcium and magnesium. Magnesium is the most expensive chemical so it is used the most infrequently. Lime, a form of magnesium hydroxide, is used to prevent and cure sickness in livestock. Lime is widely used by farmers in agriculture. Effective sludge or lime materials should be formulated to reach and sustain a pH over 12. The longer the sludge reaction time (the longer it sits at pH greater than 12) the more lethal it becomes to bacteria; the easier it will be to fight off infection. Farmers use the sludge to kill off bacteria including Salmonella as well as the Poliovirus and Parvovirus.⁹ Magnesium is a critical nutrient for grain

⁶ Information was referenced from http://www.healthwell.com/healthnotes/Drug/Magnesium_Hydroxide

⁷ Information was referenced from <http://shop.store.yahoo.com/animalmedicstore/rumbolbyag50.html>

⁸ Information was referenced from http://www.healthwell.com/healthnotes/Drug/Magnesium_Hydroxide

⁹ Information was referenced from <http://www.iwaponline.com/wio/2002/02/pdf/wio200202013.pdf>

production. A good indicator if crops are experiencing a magnesium deficiency is leaf curling and mild yellowing, also known as intervenial chlorosis. Dolomitic lime (containing both calcium and magnesium) and magnesium oxide are common magnesium fertilizers. Soil testing and tissue analysis is carried out to see at what rate fertilizer should be applied, if needed at all. If no soil test data is available, 20-30 lb Mg/a is an acceptable amount. Farmers most commonly use dolomitic lime for fertilizing needs because it is generally safe.¹⁰

Organic Materials and Practices List

603-025-0300

Livestock Production Materials and Practices

No supplements to regular feed shall be used in livestock production for a complying product other than:

(e) Dolomite

(j) Minerals, naturally occurring and synthetic. Bone meal is prohibited for use in animal feed;

Organic farmers may use magnesium in the dolomitic form for the production of livestock. Organic farmers use Rumalax to aid livestock with digestive problems.¹¹

OFPA, USDA Final Rule:

The NOP states in section 205.238 that “the producer of an organic livestock operation must not: (2) administer any animal drug, other than vaccinations, in the absence of illness. Organic farmers are not allowed to give unnecessary medicines to livestock. As in section 205.600 of the NOP final rule, “any synthetic substance used as a processing aid or adjuvant will be evaluated against the following criteria: (2) the substance’s manufacture, used and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling.” Magnesium hydroxide/oxide is not explicitly listed in section 205.603 as a synthetic substance allowed for use in organic livestock production nor is it listed in section 205.604 as a prohibited substance.¹²

OFPA, 1990, states:

6508 PROHIBITED CROP PRODUCTION PRACTICES AND MATERIALS

(b) **Soil Amendments.** For a farm to be certified under this chapter, producers on such farm shall not

(1) use any fertilizers containing synthetic ingredients or any commercially blended fertilizers containing materials prohibited under this chapter or under the applicable State organic certification program;¹³

¹⁰ Information was referenced from <http://www.ces.ncsu.edu/resources/crops/ag580/limepho.htm>

¹¹ Information was referenced from <http://www.efn.org/~forestry/standards.html>

¹² This information was referenced from <http://www.ams.usda.gov/nop/regtext.htm>

¹³ Information was referenced from <http://www.ams.usda.gov/nop/orgact.htm>

This section of the Organic Farmers Protection Act of 1990 says that certified farmers are prohibited from using any fertilizers that contain synthetic materials or any commercially blended fertilizers. Magnesium hydroxide occurs naturally and is better known as brucite in its natural state. The use of magnesium hydroxide in fertilizers does not violate this act and is deemed safe for organic farming use.

Magnesium hydroxide and magnesium oxide are currently under review by the USDA. There is no official ruling at this time and are petitioned to be reviewed in September 2002.¹⁴

Regulatory: EPA/NIEHS/Other Sources

FDA:

On March 27, 1991, the FDA issued a report recalling 50 Magnesium Oxide Bolus Jars for use in cattle. The recall was attributed to deviations in good manufacturing practices. The distribution was nationwide. The FDA first deemed magnesium hydroxide safe on April 5, 1985 (50 FR 13559). It was later amended on January 5, 1999 (64 FR 405).¹⁵ The Miscellaneous Food Additives Regulations, 1995, has deemed magnesium hydroxide suitable for general food use.¹⁶ As found in part 184, the FDA has deemed magnesium hydroxide safe as of April 1, 2001. The code of federal regulations, title 21, which concerns food and drugs states:

Part 184-Direct food substances affirmed as generally recognized as safe

Sec. 184.1428 Magnesium hydroxide.

Sec. 184.1431 Magnesium oxide.

Sub Part B-Requirements for specific standardized cereal flours and related products

Sec. 155.170 Canned peas. (magnesium oxide, magnesium hydroxide, magnesium carbonate)

Part 582-Substances generally recognized as safe

Sub Part B-General purpose food additives

Sec. 582.1428 Magnesium hydroxide.

Sec. 582.1431 Magnesium oxide.¹⁷

"November 12, 1996

FDA PUBLISHES FINAL RULE ON EXTRALABEL DRUG USE IN ANIMALS

In the November 7, 1996 *Federal Register*, FDA published a final rule to allow veterinarians to prescribe extralabel uses of certain approved animal drugs and approved human drugs for animals under certain conditions. This action implements the Animal Drug Use Clarification Act of 1994 (AMDUCA). This

¹⁴ Information was referenced from www.ams.usda.gov/nop/Materials/May2002

¹⁵ Information was referenced from <http://www.fda.gov/bbs/topics/ENFORCE/ENF00023.html>

¹⁶ Information was referenced from http://www.hmsa.gov.uk/si/si1995/Uksi_19953187_en_3.htm

¹⁷ Information was referenced from

<http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfPCD/ShowCFR.cfm?FR=184.1428>

regulation provides veterinarians with greater flexibility in the use of approved drugs in animals. These regulations put AMDUCA into effect on December 9, 1996.

The notice of proposed rulemaking published in the *Federal Register* on May 17, 1996. FDA received and considered approximately 110 comments in preparing the final rule.

Prior to the enactment of AMDUCA, the Federal Food, Drug, and Cosmetic Act (the Act) required users of approved new animal drug products to follow the exact directions on the labeling of the drug. This extralabel use restriction precluded use of an approved drug in species or for indications (disease or other conditions) not listed in the labeling, use of an approved drug at dosage levels higher than those stated on the label, and other extralabel purposes. In addition, the Act did not provide for the use of human drugs for treating animals.

Because of AMDUCA, the Federal Food, Drug, and Cosmetic Act will now permit veterinarians, like physicians, to prescribe extralabel uses of approved drugs for their patients. Although certain restrictions have been placed on veterinarians prescribing animal and human drugs in an extralabel manner, these restrictions generally apply only to the use of drugs extralabelly in food-producing animals. The key constraints are that any extralabel use must not result in violative residues in food-producing animals, the use must be by or on the order of a veterinarian within the context of a veterinarian-client-patient relationship, and the use must be in conformance with the new regulations.

AMDUCA includes a number of provisions that permit the Agency to restrict extralabel use in certain circumstances. For example, if there is a finding that there is a reasonable probability that an extralabel use may present a risk to public health from drug residues in animal-derived food, the Agency may establish a safe level for a residue for such extralabel use by regulation or order and may require the development of analytical methods for residue detection. If, after affording an opportunity for public comment, FDA finds that an extralabel animal drug use presents a risk to public health or that no analytical method has been developed and submitted, the Agency may prohibit such extralabel use. The following prohibitions currently apply to the uses of drugs in food-producing animals:

Chloramphenicol
Clenbuterol
Diethylstilbestrol (DES)
Dimetridazole
Iprnidazole
Other nitroimidazoles
Furazolidone (except for approved topical use)
Nitrofurazone (except for approved topical use)
Sulfonamide drugs in lactating dairy cattle (except approved use of sulfadimethoxine, sulfabromomethazine and sulfaethoxyypyridazine)

Neither AMDUCA nor the implementing regulations are intended to lessen the responsibility of the manufacturer, the veterinarian, or the food producer with regard to drug residues. Under AMDUCA, any amount of residue resulting from an extralabel use would constitute a violation of the Act if a safe level or tolerance has not been established.

Title 21 of the *Code of Federal Regulations* is now amended to add a new part 530, titled "Extralabel Drug Use in Animals."¹⁸

Magnesium Hydroxide/Oxide is allowed for extralabel animal used in food-producing animals because it is not explicitly prohibited.

¹⁸ Information was copied directly from <http://www.fda.gov/cvm/index/amducca/amducatoc.htm>

EPA:

The EPA has deemed magnesium hydroxide environmentally safe. This assessment is based on toxicology reports provided by the Center for Disease Control. Magnesium hydroxide is not listed on the EPA's list of regulated chemicals.¹⁹

. The Certified Organic Management Standards (March 2002) require that soil fertility be evaluated and managed. Section 3.11.2 references that soil tests are required to know the exact amount of magnesium present. Section 6.6.2 of these standards allows limestone to be used as in aid in growing media.

NFPA Ratings: Health: 1 Flammability: 0 Reactivity: 0

**Livestock Medicines Act
Loi sur les médicaments pour le bétail**

REVISED REGULATIONS OF ONTARIO

REGULATION 730

*Amended to O. Reg. 291/97***GENERAL**

This Regulation is made in English only.

1. In this Regulation,

"biological" means a bacterin, vaccine, toxoid, antiserum or antitoxin prepared for use in the prevention or treatment of livestock diseases. R.R.O. 1990, Reg. 730, s. 1.

2. Subject to the *Food and Drugs Act* (Canada) and the Food and Drug Regulations made thereunder, the drugs and classes of drugs designated in the Schedule are designated as livestock medicines for the purposes of the Act and this Regulation. R.R.O. 1990, Reg. 730, s. 2.

3. (1) The following classes of licences are established:

1. Class 1.

2. Class 2.

R.R.O. 1990, Reg. 730, s. 3 (1); O. Reg. 291/97, s. 1 (1).

(2) A livestock medicine set out in the Schedule is designated as a livestock medicine that may be sold by the holder of a Class 1 licence at the holder's established place of business.

(3) A Class 2 licence authorizes the holder of a Class 1 licence to sell at a temporary place of business the livestock medicines that the holder is authorized to sell at the holder's established place of business. O. Reg. 291/97, s. 1 (2).

¹⁹ Information was referenced from a phone interview with George Prince, CDC, June 5, 2002.

(4) Revoked: O. Reg. 291/97, s. 1 (2).

4. (1) The applicant for a Class 1 licence shall send to the Director an application accompanied by payment of the fee of \$75.

(2) A Class 1 licence is valid up to and including July 31 after it is issued. O. Reg. 291/97, s. 2.

5. (1) The holder of a Class 1 licence may obtain a Class 2 licence by sending to the Director an application accompanied by payment of the fee of \$50.

(2) A Class 2 licence is valid only for the period shown on it. O. Reg. 291/97, s. 2.

5.1 A licence is not transferable. O. Reg. 291/97, s. 2.

6. (1) A licence is issued on the terms and conditions that the licensee,

(a) shall continue to have an established place of business for the storage and sale of livestock medicines;

(b) shall keep for sale or sell livestock medicines only at the established or temporary place of business described on the licence;

(c) shall not keep for sale or sell any livestock medicines after the expiration date indicated by the manufacturer on the label thereof;

(d) shall not repackage or relabel livestock medicines;

(e) shall not deliver a livestock medicine except for dairy sanitizers, teat dips and udder washes to a livestock owner without an order from that owner authorizing the delivery evidenced by an invoice prepared by the licensee in advance of delivery;

(f) shall keep refrigerated all livestock medicines that require refrigeration;

(g) shall store in the manner prescribed by this Regulation all livestock medicines that do not require refrigeration; and

.....

(i) shall not sell a livestock medicine to any person other than an owner of livestock or for any purpose other than the treatment of livestock. R.R.O. 1990, Reg. 730, s. 6 (1); O. Reg. 636/91, s. 2 (1, 2); O. Reg. 291/97, s. 3 (1).

(2) A Class 2 licence shall be issued only for a temporary place of business that is located on premises where livestock are assembled in connection with an agricultural exhibition, a horse show or the holding of horse races. O. Reg. 291/97, s. 3 (2).

7. (1) A licensee who maintains, handles or stores livestock medicines shall keep them in a refrigerator, cabinet or other storage facility that is used solely for that purpose.

(2) A licensee shall ensure that livestock medicines, whether they require refrigeration or not, are maintained at the temperatures prescribed for them by the manufacturer and that they do not come in contact with food or medicine for human consumption. O. Reg. 636/91, s. 3.

(3) The licensee shall maintain every refrigerator, cabinet or other storage facility in a clean and sanitary condition. O. Reg. 291/97, s. 4.

8. (1) Every licensee shall,

(a) sell every livestock medicine in the container in which it is received by the licensee;

(b) in the case of any livestock medicine bearing a warning or caution on the label, draw the attention of the purchaser to the warning or caution; and

(c) immediately after the expiration date indicated by the manufacturer on the label of a livestock medicine, remove the livestock medicine from sale and keep it separate from other livestock medicines until it is disposed of in a manner approved by the Director.

(2) No licensee shall engage in any practice by which a livestock medicine is held out as an inducement for the purchase of livestock medicines or other goods, or by which other goods are held out as an inducement for the purchase of livestock medicines.

(3) No licensee shall store or permit to be stored any food or medicine for human consumption in a refrigerator, cabinet or facility used for the storage of livestock medicines. R.R.O. 1990, Reg. 730, s. 8.

9. (1) Every licensee shall keep accurate records of the livestock medicines sold by the licensee, and the record of each sale shall include,

(a) the date of the sale;

(b) the name and address of the purchaser;

(c) the brand name and quantity; and

(d) the lot numbers of any biologicals.

(2) Every record of a sale of livestock medicines shall be kept for a period of at least two years. R.R.O. 1990, Reg. 730, s. 9.

10. No advertising in respect of livestock medicines by a licensee shall exceed the claims or information set out on the manufacturer's label. R.R.O. 1990, Reg. 730, s. 10.

11. (1) Where an inspector seizes, removes or detains any livestock medicine under clause 3 (5) (c) of the Act, the inspector shall,

(a) attach thereto a tag bearing a serial number and the words "Ont. Detained";

(b) forthwith thereafter notify the owner or the person who had possession thereof in writing of,

(i) the seizure, and

(ii) the grounds on which the seizure was made; and

(c) direct that the livestock medicine be detained in the place where it was found or be removed to another place designated by him or her.

(2) Where a livestock medicine is detained, no person shall,

(a) remove the tag attached to it; or

(b) sell, offer to sell, move or allow or cause to be moved such livestock medicine.

(3) Where an inspector is satisfied that,

(a) the licensee is not contravening the Act or this Regulation with regard to a livestock medicine that is detained; or

(b) the person whose livestock medicine is detained is authorized to sell livestock medicines to owners of livestock for the treatment of livestock,

the inspector shall remove the attached tag and release the livestock medicine from detention.

(4) Where,

(a) after a hearing, the Director finds,

(i) that there is a contravention of the Act or this Regulation by the licensee whose livestock medicine is detained, or

(ii) that the person whose livestock medicine is detained is not authorized to sell livestock medicines to owners of livestock for the treatment of livestock; or

(b) a person is convicted of an offence against the Act or this Regulation in respect of livestock medicine that is detained,

the Director may direct that the livestock medicine be destroyed or disposed of in such manner as he or she considers advisable.

(5) Any proceeds realized from the disposal of livestock medicine under subsection (4) shall be paid to the Minister of Finance. R.R.O. 1990, Reg. 730, s. 11.

12. Where a licence is refused, suspended or revoked, any livestock medicines in the possession of the applicant or licensee shall be removed and disposed of under the supervision of an inspector by,

(a) their sale to a person authorized to sell livestock medicines;

(b) their return to the supplier of the livestock medicines; or

(c) any other method satisfactory to the Director. R.R.O. 1990, Reg. 730, s. 12.

13. In addition to the grounds mentioned in section 6 of the Act, the Director may refuse to renew or may suspend or revoke a licence where the licensee sells any drug other than a livestock medicine. R.R.O. 1990, Reg. 730, s. 13.²⁰

²⁰ Copied directly from http://192.75.156.68/DBLaws/Regs/English/900730_e.htm

Status Among U.S. Certifiers

The Texas Department of Agriculture does have Magnesium hydroxide on their Organic Materials List. (Contact- Leslie McKinnon- Coordinator for Organic Certification)²¹

Ohio is in accordance with OMRI criterion. Magnesium hydroxide is allowed but is restricted. It can be used as a feed additive. It can only be used for trace minerals. (Contact- Steve Sears- Certification Administrator)²²

Oregon does not have specific limitations on materials used for crops and livestock. If the materials comply with USDA regulations, they are deemed acceptable for use in the state of Oregon. (Contact- Ron McKay)²³

Pennsylvania is in accordance with guidelines proposed by OMRI. (Contact- Martha Melton)²⁴

International

IFOAM: Basic standards 2002- not explicitly listed as approved food additive or processing aid²⁵

CODEX: Magnesium hydroxide meets the requirements set forth in the Food Chemical Codex, 3rd ed. Assuming good manufacturing practices, magnesium hydroxide is recognized as an acceptable, safe food ingredient

NORWAY: Norway has set up the Norwegian State Pollution Control Authority (SFT), which enforces permits for any drilling of fluids/muds. Norway acts in accordance with OSPAR regulations. Magnesium hydroxide is listed as a chemical requiring a much reduced discharge rate, despite the full known toxicology of the compound. The discharge of unused chemicals is strictly forbidden and enforced in Norway.²⁶

EU: The European Union (EU) and the US vary greatly in their limitations on sludge and how it should be treated to prevent disease in livestock. The EU allows more freedom when considering how sludge will be used for treatment. The US requires disposal classification of the sludge before it can be used for treatment. BIO-GRO, New Zealand organic standards have approved magnesium limestone as an acceptable fertilizer. BIO-GRO states that the fertilizer is acceptable if it is from its natural origin.²⁷ Various international eco-label programs including Blue Angel (Germany), Ecomark (India), Environmental Choice (Canada), European Union, Green Seal (United States), and Nordic Swan (Norway, Sweden, Denmark, Finland, Iceland) do site flame-retardants as chemicals to avoid. Even though magnesium is a flame retardant, it is cited as an alternative *solution* to those you should avoid. Magnesium is deemed acceptable because it is a non-halogenated flame retardant. Other alternatives provided by eco-

²¹ Information was referenced from email correspondence with Leslie McKinnon, Coordinator for Organic Certification, June 4, 2002.

²² Information was referenced from a phone interview with Steve Sears, Certification Administrator, June 5, 2002.

²³ Information was referenced from a phone interview with Ron McKay, State Certifier, June 5, 2002.

²⁴ Information was referenced from a phone interview with Martha Melton, State Certifier, June 5, 2002

²⁵ This information was referenced from http://www.ifoam.org/standard/ibs_final02.html

²⁶ Information was referenced from <http://www.offshore-environment.com/norway.html>

²⁷ Information was referenced from http://www.biogro.co.nz/files/1010430_livestock.pdf

labeled programs include borates, boronic acids, and phosphorus based materials.²⁸ Magnesium hydroxide/oxide are listed as permitted substances in the EU standards.²⁹

JAPAN: not specifically listed in Japanese Rule³⁰

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

- 1. The potential of the substance for detrimental interactions with other materials used in organic farming systems.*

None if dolomitic lime is used as a fertilizer.

- 2. The toxicity and mode of action of the substance and of its break down products or any contaminants, and their persistence and areas of concentration in the environment.*

Although magnesium hydroxide is poorly absorbed, toxins may build up in the body of a renal impaired patient. High levels of toxins in the blood may cause flushed skin, extreme thirst, hypertension, respiratory depression, and the blocking of neuromuscular transmission.³¹ The fatal dose of the magnesium ion in humans is approximately 30mg/kg which would raise serum magnesium levels in the body to 13-15 meq/L, a lethal level. The likelihood of such an occurrence is rare. Fatality is minimal. The prolonged use of Mg(OH)₂ may cause renal stones comprised up Mg(CO)₃ and Mg(OH)₂. Systemically, magnesium can depress the central nervous system in the body, hinder reflexes, and finally cause death from respiratory paralysis.³²

- 3. The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*

Aluminum and magnesium phosphide are very hazardous to the environment. Non-targeted water supplies and organisms aren't as high a risk as those species targeted by the pesticides. In the environment these pesticides, aluminum and magnesium phosphide, decompose rapidly into aluminum and magnesium hydroxide which decompose even faster. Aluminum and magnesium hydroxide pose little to no environmental risks specifically to water supplies. Magnesium hydroxide occurs naturally in the brucite form posing a negligible affect on the environment even if it should happen to be misused or discarded incorrectly. It degrades very quickly. Causmag TGM is a magnesium oxide product which is used in waste water treatments. It is extremely water soluble, ensuring a short operation time with little sludge disposal problems that may have adverse environmental effects.³³

- 4. The effects of the substance on human health.*

Generally speaking, humans should not have a problem with magnesium hydroxide if used as a laxative or an antacid as approved by the FDA. Magnesium hydroxide is a liming material. It is also used by farmers, in large quantities, for cattle. Farmers use what is called Rumalax Bolus. It is a drug administered orally which contains a large amount of magnesium hydroxide (27 g/bolus) as well as

²⁸ Information was referenced from <http://www.moea.state.mn.us/berec/dfc-materials.cfm#programs>

²⁹ Referenced from http://www.foodstandards.gov.uk/multimedia/pdfs/elist_numbers.pdf

³⁰ Directly referenced from <http://www.fas.usda.gov/gainfiles/200004/25647377.pdf>

³¹ Information was referenced from <http://www.paddocklabs.com/madspdf/MILKOMAG.PDF>

³² Information was referenced from <http://toxnet.nlm.nih.gov/cgi-bin/sis/search>

³³ Information was referenced from <http://www.magnesiainternational.com/home.htm>

ginger, capsium, and methyl salicylate. This large concentration is intended for cattle with digestive problems only. This is for animal use only and can affect human health if digested or misused. Magnesium hydroxide will irritate eyes and skin if exposed.³⁴

MAGNESIUM HYDROXIDE

Human Health Effects:

Human Toxicity Excerpts:

PROLONGED USE OF MG(OH)₂ MAY RARELY CAUSE RECTAL STONES COMPOSED OF MGCO₃ & MG(OH)₂.

[Gilman, A. G., L. S. Goodman, and A. Gilman. (eds.). Goodman and Gilman's The Pharmacological Basis of Therapeutics. 6th ed. New York: Macmillan Publishing Co., Inc. 1980. 993]**PEER REVIEWED**

FATAL DOSE OF ABSORBED MAGNESIUM ION IS APPROX 30 MG/KG, AN AMT WHICH WOULD RAISE SERUM MAGNESIUM TO LETHAL LEVEL OF 13-15 MEQ/L... FATALITIES ARE RARE.

[Dreisbach, R. H. Handbook of Poisoning. 9th ed. Los Altos, California: Lange Medical Publications, 1977. 412]**PEER REVIEWED**

IF EVACUATION FAILS (BOWEL OBSTRUCTION OR ATONY), MUCOSAL IRRITATION & ABSORPTION OCCUR. SYSTEMICALLY MG PRODUCES CNS DEPRESSION, ABOLITION OF REFLEXES, & DEATH FROM RESP PARALYSIS.

[Gosselin, R.E., H.C. Hodge, R.P. Smith, and M.N. Gleason. Clinical Toxicology of Commercial Products. 4th ed. Baltimore: Williams and Wilkins, 1976.,p. II-88]**PEER REVIEWED**³⁵

MAGNESIUM OXIDE

CASRN: 1309-48-4

For other data, click on the Table of Contents

Human Health Effects:

Human Toxicity Excerpts:

EXAM OF 95 MEN EXPOSED TO MGO DUST REVEALED ONLY SLIGHT IRRITATION OF EYES & NOSE, ALTHOUGH MG LEVEL IN SERUM OF 60% OF THOSE EXAMINED WAS ABOVE NORMAL UPPER LIMIT OF 3.5 MG%... EXPTL METAL FUME FEVER IN MAN HAS HOWEVER, BEEN PRODUCED BY EXPOSURE TO EXCESSIVE CONCEN OF FRESH MGO FUME...

[Patty, F. (ed.). Industrial Hygiene and Toxicology: Volume II: Toxicology. 2nd ed. New York: Interscience Publishers, 1963. 1078]**PEER REVIEWED**

...WORKERS OBSERVED...PRONOUNCED LEUKOCYTOSIS ANALOGOUS TO THAT CAUSED BY ZINC OXIDE /WITH REACTIONS OF METAL FUME FEVER CAUSED BY MGO EXPOSURE/.

[Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 210]**PEER REVIEWED**

³⁴ Information was referenced from <http://shop.store.yahoo.com/animalmedicstore/rumbolbyag50.html>

³⁵ Copied directly from <http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~AAAcHa4XB:1>

ACUTE MAGNESIUM TOXICITY CAUSES NAUSEA, MALAISE, GENERAL DEPRESSION, & PARALYSIS OF RESP, CARDIOVASCULAR, & CENTRAL NERVOUS SYSTEMS. TOXIC EFFECTS OF MAGNESIUM ON CNS ARE DUE TO DECR LIBERATION OF ACETYLCHOLINE @ NEUROMUSCULAR JUNCTION & SYMPATHETIC GANGLIA. /MAGNESIUM/
 [Luckey, T.D. and B. Venugopal. Metal Toxicity in Mammals, 1. New York: Plenum Press, 1977. 168]**PEER REVIEWED**

HYPOTENSION, CUTANEOUS VASODILATION, & CARDIAC ARREST ARE MAJOR MAGNESIUM TOXICITY SYMPTOMS OF CARDIOVASCULAR SYSTEM. DEPRESSION OF CARDIAC MUSCLE ACTIVITY & HYPOXIA, SECONDARY TO PARALYSIS OF RESP TISSUES, ARE RESPONSIBLE FOR LOCAL INTRASPINAL & GENERAL ANESTHETIC EFFECTS OF MAGNESIUM TOXICITY. /MAGNESIUM/
 [Luckey, T.D. and B. Venugopal. Metal Toxicity in Mammals, 1. New York: Plenum Press, 1977. 168]**PEER REVIEWED**

...4 HUMAN SUBJECTS WERE EXPOSED @ MEASURED CONC N OF FRESHLY GENERATED **MAGNESIUM OXIDE** FUME. ALTHOUGH SLIGHT REACTIONS WERE OBSERVED AFTER LESS THAN 10 MIN OF EXPOSURE @ CONC N OF APPROX 400-600 MG/CU M, IT WAS BELIEVED THAT MORE SEVERE EXPOSURES WOULD LEAD TO MORE SEVERE REACTIONS. [American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values for Substances in Workroom Air. Third Edition, 1971. Cincinnati, Ohio: AmericanConference of Governmental Industrial Hygienists, 1971. (Plus supplements to 1979) 147]**PEER REVIEWED**

MAGNESIUM SALTS ARE PRACTICALLY NONTOXIC BY ORAL ADMIN, SINCE EFFECTIVE HOMEOSTASIS OPERATES IN INTESTINAL ABSORPTION. /MG SALTS/
 [Luckey, T.D. and B. Venugopal. Metal Toxicity in Mammals, 1. New York: Plenum Press, 1977. 167]**PEER REVIEWED**³⁶

5. *The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms(including the salt index and solubility of the soil), crops and livestock*

Several chemical reactions take place between lime, fertilizers, and the soil to which they both are applied. Soil particles have been layered with oxides and organic materials adding to the chemical reactions taking place when fertilizers are applied to the soil. Magnesium hydroxide is a type of fertilizer that can be used in helping crops grow. The positive charge from the magnesium (cation) reacts with the negative charge on the soil. The two charges are attracted to one another. Liming materials may be carbonates, oxides, or hydroxides. The finer the chemical form becomes, the faster the reaction time. Magnesium hydroxide and oxide are also known as hydrated lime and burned lime respectively. Hydroxides and oxides are more water-soluble thus greatly surpassing the reaction time of carbonates. For ideal crop grow, lime should be used as fertilizer to adjust the pH level of the soil. Magnesium hydroxide will only interact with the soil and will not be harmful to other soil surface organisms. It is the soil's negative charge reacting with the magnesium's positive charge.³⁷

6. *The alternatives to using the substance in terms of practices or other available materials.*

³⁶ Copied directly from <http://toxnet.nlm.nih.gov/cgi-bin/sis/search/?/.temp/~AAAsqaybF:1>

³⁷ Information was referenced from <http://www.ca.ukv.edu/agc/pubs/agr/agr5/agr5.htm>

In Alberta, Canada, forestry plants burn saw dust, bark, etc. to generate electricity. The wood ash remnants have actually been documented as an excellent fertilizer, improving crop growth. Improved growth was noted especially in areas where windows were burned. Alberta Environment, in conjunction with the Alberta Forest Products Association and Alberta Agriculture is currently developing guidelines for wood ash use as a liming material.³⁸ Other alternative liming agents, fertilizers, include calcium hydroxide, calcium oxide, and calcium limestone. Organic farmers may also use natural forms of phosphorous as a fertilizer. Animal manures are a good source of phosphorous, nitrogen, and other nutrients. One caveat about animal manures; they may contain high levels of nitrates and ammonia if used in their raw form. Animal manures cannot be used for foods intended for human consumption. They will be in violation of the OFPA of 1990.

6513 ORGANIC PLAN

(2) Manuring.

(A) Inclusion in Organic Plan. An organic plan shall contain terms and conditions that regulate the application of manure to crops.

(B) Application of Manure. Such organic plan may provide for the application of raw manure only to

- (i) any green manure crop;
- (ii) any perennial crop;
- (iii) any crop not for human consumptions

Organic farmers are prohibited from using ammonium sulphate as a soil additive but they may use zinc, iron, and potassium sulphates as suitable alternatives.³⁹

7. Its compatibility with a system of sustainable agriculture.

The EPA has confirmed that magnesium hydroxide is not found in ground water supplies. Therefore, unless prodigious natural deposits of magnesium hydroxide are found in the actual soil, the exposure of such a compound will not be detrimental and will not affect systems of sustainable agriculture.⁴⁰

TAP Reviewer Discussion

Reviewer 1 [Ph.D. Animal Science, M.S. Animal Science. Research and teaching activities related to dairy cattle nutrition and nutrient management on livestock farms. Southeast US]

Comments on petition

³⁸ Information was referenced from <http://www.agric.gov.ab.ca/agdex/500/534-2.html>

³⁹ Information was referenced from <http://www.ams.usda.gov/nop/orgact.htm>

⁴⁰ Information was referenced from a phone interview with Don Henderson, EPA Librarian, June 5, 2002.

The petition is somewhat vague on the specific uses being proposed for magnesium hydroxide. While the use of magnesium hydroxide as a digestive aid is well-supported in the petition, significant evidence is produced indicating that it should not be approved for use as a soil amendment or preservative. There are many alternatives to this compound for agronomic use, and its use as a preservative is explicitly banned in the Federal Organic Food Production Act.

OEPA Criteria Evaluation

(1) The potential of such substances for detrimental chemical interactions with other materials used in organic farming systems;

I agree with the criteria evaluation in the petition.

(2) The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment;

I agree with the criteria evaluation.

(3) the probability of environmental contamination during manufacture, use, misuse or disposal of such substance;

I agree with the criteria evaluation.

(4) the effect of the substance on human health;

I agree with the criteria evaluation.

(5) the effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock;

I agree with the criteria evaluation.

(6) the alternatives to using the substance in terms of practices or other available materials; and

I agree with the criteria evaluation. As noted, there are several alternatives to magnesium hydroxide available for agronomic use, but no organic alternatives to its use in treatment of digestive upsets of livestock.

(7) its compatibility with a system of sustainable agriculture.

I agree with the criteria evaluation.

Reviewer 1 Conclusion

The substance is not synthetic, as it is found naturally.

Reviewer 1 Recommendation Advised to the NOSB:

The substance is Not Synthetic

For Livestock, the substance should be Added to the National List with restrictions.

I recommend magnesium hydroxide be approved synthetic-allowed with restrictions on its use. It should be approved only for treatment of digestive upsets (upset stomach, constipation) in livestock.. Land-application of biosolids (which contain magnesium hydroxide) is explicitly banned in section 205.203 e.2 of the Federal Organic Food Production Act; this petition can not and should not supersede that agronomic ban. Likewise, use of compounds as a preservative is explicitly banned in section 205.600 b.4 of the Federal Organic Food Production Act. This petition can not and should not supersede the ban on use of preservatives.

When used to treat digestive upsets, there are no organic substitutes for magnesium hydroxide, and its manufacture, use, and disposal do not have adverse effects on the environment. The nutritional quality of food (milk, meat) is maintained when it is used and it does not have adverse effect on human health. It is listed as GRAS by FDA, is not proposed for use as a preservative, and is necessary to the production of

organically produced agricultural product. Listing this product with the limitation indicated is consistent with the action of individual states (Texas, Ohio).

Reviewer #2: [Ph.D. Food Science, Regents Professor and Director, Southeast U.S.]

Comments on Database

There are a few inconsistencies or inaccuracies in the database that should be corrected. These include:

1. In the "Specific Uses" section, lime is described as "any material that contains magnesium or calcium and will neutralize soil activity." In addition, in the "Historic Use by Organic Farmers" section lime is described as "a form of magnesium hydroxide." The scientific definition of lime is calcium oxide. Lime of commerce contains 90-95% free CaO. Magnesium hydroxide is not a major component of lime, hence the definition for lime included in the database is incorrect.
2. Also in the "Specific Uses" section, it is indicated that "magnesium hydroxide helps both crops and livestock by both preventing and curing diseases." This is not completely accurate because Mg(OH)₂ does not cure plant and animal diseases. Rather, it is used in cattle as a "pain reliever" to provide temporary relief of an upset stomach (antacid) and short-term relief of constipation (laxative). Magnesium hydroxide is used in crop production primarily as a source of minerals for the soil (fertilizer) and not to cure diseases in crops.
3. In the "Historic Use by Organic Farmers" section, there is considerable discussion regarding the use of lime in agriculture but this is irrelevant because lime (CaO) and magnesium hydroxide are entirely different chemicals.
4. In the "Action" section, there is considerable detail provided regarding the potential adverse effects of prolonged exposure to antacids. Antacids frequently contain other chemicals besides Mg(OH)₂ which may be primary contributors to the adverse reactions in humans to antacids. Information provided should be specific to Mg(OH)₂ and a better analysis of the facts needs to be provided if mixtures of chemicals are used.

OFPA Criteria Evaluation

1. *The potential of such substances for detrimental interactions with other materials used in organic farming systems.*

None if used as dolomite as a fertilizer or if used at recommended concentrations in livestock for digestive problems.

2. *The toxicity and mode of action of the substance and its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*

The likelihood of magnesium toxicity from the use of magnesium hydroxide as a soil fertilizer or as a livestock treatment when used at recommended concentrations is remote.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*

Magnesium hydroxide occurs naturally as the mineral, brucite, which degrades very quickly and has no history of negative impact on the environment.

4. The effect of the substance on human health.

Exposure to concentrated magnesium hydroxide will irritate eyes and skin; however, at appropriate concentrations, it is used as a laxative or antacid in humans. As with most chemicals, ingestion at high concentrations (e.g., 30 mg/kg), Mg(OH)₂ can be fatal in humans, but rarely.

5. Effects of the substance on biological and chemical interactions in the agro ecosystem, including the physiological effects of the substance in soil organisms, crops and livestock.

I concur with the criteria evaluation.

6. Alternatives to using the substance in terms of practices or other available materials.

I concur with the criteria evaluation.

7. Its compatibility with a system of sustainable agriculture.

There appears to be no issues associated with the compatibility of Mg(OH)₂ with sustainable agriculture.

Reviewer 2 Recommendation to the NOSB

The substance is nonsynthetic.

For crops and livestock, the substance should be added to the National List with Restrictions.

Reviewer 3 [Ph.D. Chemistry, Professor, Department of Chemistry, Southwest US]

Comments on Database

The following information needs to be corrected or added to the database:
No additional information is required.

The Technical Advisory Panel's review of potassium sorbate, its chemistry and applications is adequate to understand how the compound would be useful in livestock production.

OFPA Criteria Evaluation/Summary

Magnesium hydroxide is not a synthetic material, as it occurs naturally in the form of a mineral. It is used for both medicinal (for digestive problems) and fertilizer purposes. The minerals of magnesium are very similar to those of calcium so many applications use a combination of both (e.g., dolomitic lime).

Medicinal uses are surely permitted. There is no mention of using magnesium hydroxide in various forms as a preventative measure.

Reviewer 3 Conclusion

It is a non-synthetic material. I see no reason not to use it essentially an antacid.
Fertilizers must not be synthetic nor blended commercially. Again, magnesium hydroxide is not synthetic.

Reviewer 3 Recommendation Advised to the NOSE

In summary, I see no reason not to allow magnesium hydroxide for all indicated uses. Magnesium hydroxide is a non-synthetic material.

For Livestock, the substance should be Added to the National List without restrictions.

Appendix 3 : Publication “Analytical methods in food additives determination: Compounds with functional applications”

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Review

Analytical methods in food additives determination: Compounds with functional applications



Fernanda C.O.L. Martins^a, Michelle A. Sentanin^b, Djeneine De Souza^{a,*}

^a Laboratório de Eletroanálise Aplicada a Biotecnologia e a Engenharia de Alimentos – LEABE, Campus de Patos de Minas, Instituto de Química, Universidade Federal de Uberlândia, Av. Geníllo Vargas, 230, Centro 38700-126, Patos de Minas-MG, Brazil

^b Laboratório de Análise e Química de Alimentos, Campus de Patos de Minas, Faculdade de Engenharia Química, Universidade Federal de Uberlândia, Av. Geníllo Vargas, 230, Centro 38700-126, Patos de Minas-MG, Brazil

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ABSTRACT

This work describes the 25 classes of food additives that contain about 230 compounds with technological, sensorial and/or microbiological functionalities. These compounds are added to foods at the processing, packaging and transport steps, to improve the standard of quality, durability and stability of the product and adjust the colour, smell and flavour attributes. Food industries need to follow national and international quality standards that establish the conditions under which food additives may be used, and the food safety is guaranteed by strict quality control. This review describes the analytical techniques used in identification and quantification of food additives in foodstuffs, highlighting the main characteristics of each method (spectroscopy, chromatography and electroanalysis), and indicating the advantages and disadvantages typical of the methods used. Perspectives of the chemical analysis in the food industries are also discussed.

1. Introduction

In the last decades, the increased population and lifestyle changes promoted considerable alterations in the formulation of food products. Additionally, the transformation of the eating habits and modification in the nutritional demands caused an important transformation in the food industries, which involved the incorporation of additional food ingredients to food products. The purpose of these compounds (food additives) is to add dietary nutrition (fortifiers) (Martins, Franco, Muñoz, & De Souza, 2017), increase the shelf life and/or to improve the physicochemical, sensorial and microbiological properties of the industrialised foods (Damodaran & Parkin, 2017).

A vast variety and quantity of chemical additives are employed in industrialised foods, to maintain and/or improve the biological, physicochemical, rheological and sensorial properties, such as pH, texture, homogeneity, colour, flavour, sweetness, crunchiness, overall quality and stability, and to extend the expiry date. A plethora of compounds presenting specific functionality is used to achieve these objectives, promoting differentiated quality in industrialised foods. The food industries employ about 25 classes of food additives, which are used according to the specific legislation of each country and following a food safety policy, based on the *Codex Alimentarius* (Food and Agriculture Organisation of the United Nations/World Health Organisation [FAO/WHO], 2016).

For all approved food additives, the legislation should indicate the foods to which the food additive may be added, the conditions under which the food additive may be used and recommend the maximum permissible quantity of the additive, which is based on a level that assures consumer safety. For this, the industries and the regulatory agencies require rigorous quality control in the identification of the class of the food additives and the level of quantification at which they are employed. Ensuring that any illegal additives are avoided, also demands rigorous evaluation.

The current review describes the different classes of the food additives and the main analytical methods employed in the analysis of these compounds, indicating the advantages, disadvantages and perspectives of the chemical analysis in the food industry.

2. Food additives

According to the *Codex Alimentarius* (FAO/WHO, 2016), which is recognised as the international standard, food additives are any compound not typically consumed as a food by itself and not normally used as an ingredient in the food but is intentionally added in the manufacture, processing, preparation, treatment, packing, packaging, transport and holding of the food, to perform a technological function (including organoleptic). The term does not include additives or

* Corresponding author.

E-mail addresses: michelle@ufu.br (M.A. Sentanin), djeneine@ufu.br (D. De Souza).

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contaminants added to food for preserving or enhancing the nutritional properties. The use of food additives improves the quality of the final product and increases the shelf life of the foodstuffs on retail shelves.

In general, the food industry can only use food additives that offer a reasonable technological need that cannot be achieved by other economically and technically viable methods. In addition, these compounds cannot present a risk to the health of consumers, at the level of use proposed. Thus, the *FAO/WHO* (2017), by the implementation of the *Codex Alimentarius*, and the European Union (EU, 2017) establish the conditions under which food additives may be used by the food industries.

The well-developed food safety policies established by the *FAO* (2016) and *EU* (2017) are the point of reference for other official food authorities around the world and the creation of specific legislation in other countries. In Brazil, the National Sanitary Vigilance Agency (ANVISA) is responsible for the authorisation of the use and inspection of food additives in the industries (ANVISA, 2018). Furthermore, industries that export industrialised foods need to follow national and international quality standards, according to regulations and laws, and adequately meet the consumers' expectations, by employing an adequate amount of the food additive.

2.1. Food additives classification

The *FAO* and *EU* employ the food additives classification, according to the food type in which they may be added. The food type categories include, for example, dairy and dairy-based products, fats and oils, edible ices, fruits and vegetables, confectionery, cereal and cereal products, eggs and eggs products, sweeteners, salts, spices, soups, sauces, salads, protein products, foodstuffs intended for nutritional uses, beverages, ready-to-eat savouries and prepared foods (FAO/WHO, 2016).

According to the industrial use, the food additives are classified into 25 classes, which include about 230 different compounds. Some compounds present more than one principal action, due to their different functionalities, which are dependent on the added quantities and processing mode of the food. Fig. 1 shows the relative percentage of each food additive, considering the functional classes.

The main technological functions of food additives involve pH control, viscosity, stability and homogeneity; the biological functions are related to stability, degradation process inhibition and shelf life; and/or the sensorial functions include, among others, colour, smell and flavour. The concentration of the incorporated additive, the step at which it is added, the mode in which it is added and the food type, can be adjusted, according to the desired functionalities. Table 1 shows the function and uses of the respective food additives, as described above.

2.1.1. Acidity regulators

The acidity regulators are substances capable of controlling or modifying the pH of foodstuffs, thereby influencing the smell, flavour, viscosity, texture and, mainly, shelf life, by directly impacting on the oxidation/enzymatic reactions and inhibition of microbiological growth. These compounds are constituted by organic acids, inorganic acids, bases and conjugated salts, and can act alone or in conjunction with the buffering system (Belitz, Groch, & Schieberle, 2009).

The organic acids mainly used as acidity regulators are acetic, citric, malic, benzoic and formic. These acids act as food preservatives, chelating or sequestrant agents, in the setting of pectin gels, emulsifiers, sterilisers, anti-foamers and flavouring agents. The most common basic acidity regulators are salts of the phosphates, lactates and citrates, employed for pH stabilisation, producing a buffering in the foodstuffs system, colour retention and complexation reactions of metals, to improve the sensorial quality of the foodstuffs. Strong inorganic acids and bases are also used in the processing of vegetables and fruits (Msagati, 2012).

Sometimes the pH must be alternated during the industrial process, by using a buffer system, according to the desired pH values. The most common buffer systems employed are citric acid/sodium citrate (pH 2.1–4.7), acetic acid/sodium acetate (pH 3.6–5.6) and ortho- and pyrophosphate anions (pH 2.0–12.0). These buffers aid in pH control for protein stabilisation, without causing alterations to the smell and flavour of the food (Damodaran & Parkin, 2017).

2.1.2. Anticaking agents

In powdered foods, agglutination and lump formation can occur, which decrease the quality and interfere in the solubility and sensorial

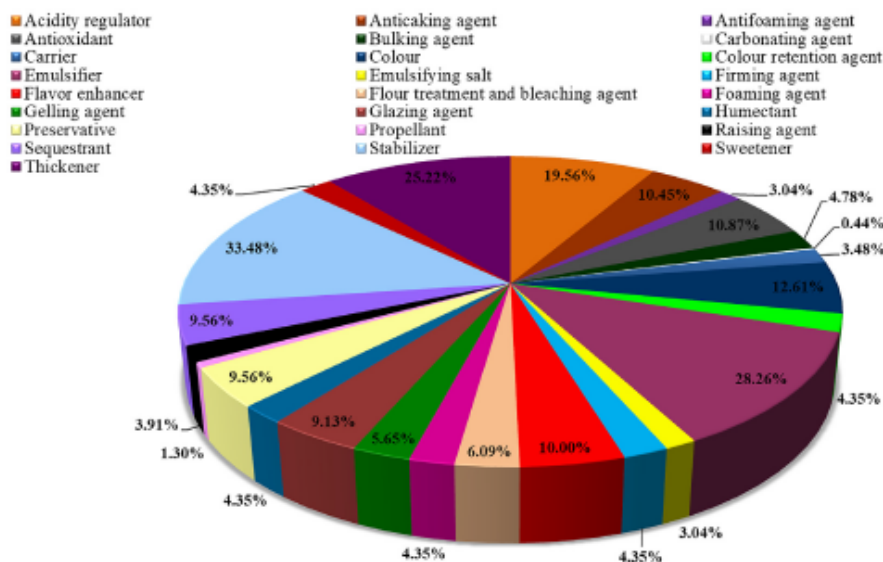


Fig. 1. Perceptual relationship of each class of the food additives use in food industries.

Table 1

Chemical additives used in food industries according main technological functions (FDA-U.S. Food Administr., 2018); (Food and Agriculture Organization of the United Nations World Health Organization, 2016).

Class	Additives
1 Acidity regulator	Glacial acetic acid; Adipates; Aluminum ammonium sulfate; Ammonium carbonate; Ammonium hydrogen carbonate; Ammonium hydroxide; Ascorbic acid, L; Calcium carbonate; Calcium hydroxide; Calcium lactate; Calcium oxide; Citric Acid; Fumaric Acid; Glucono delta-lactone; Hydrochloric acid; Lactic acid, L-, D- and DL; Magnesium Carbonate; Magnesium hydroxide; Magnesium hydroxide carbonate; Magnesium oxide; Malic acid, DL; Phosphoric acid; Sodium dihydrogen phosphate; Trisodium phosphate; Phosphates; Potassium acetate; Potassium carbonate; Potassium dihydrogen citrate; Potassium hydrogen carbonate; Potassium hydroxide; Potassium lactate; Sodium acetate; Sodium aluminum phosphates; Sodium carbonate; Sodium diacetate; Sodium dihydrogen citrate; Sodium DL-malate; Sodium fumarates; Sodium hydrogen carbonate; Sodium hydroxide; Sodium lactate; Sodium sesquicarbonate; Tartarates; Tricalcium citrate; Tripotassium citrate; Trisodium citrate;
2 Anticaking agent	Calcium silicate; Carnauba wax; Castor oil; Ferric ammonium citrate; Ferrocyanides; Magnesium hydroxide carbonate; Magnesium oxide; Magnesium silicate, synthetic; Mannitol; Microcrystalline cellulose (cellulose gel); Phosphates; Polydimethylsiloxane; Powdered cellulose; Salts of myristic, palmitic and stearic acids with ammonia, calcium, potassium and sodium; Salts of oleic acid with calcium, potassium and sodium; Silicon dioxide, amorphous; Sodium aluminosilicate; Sodium carbonate; Sodium hydrogen carbonate; Sodium sesquicarbonate; Talk;
3 Antifoaming agent	Calcium alginate; Microcrystalline wax; Mono- and di-glycerides of fatty acids; Polydimethylsiloxane; Polyethylene glycol; Polysorbates; Silicon dioxide, amorphous;
4 Antioxidant	Ascorbic acid, L; Ascorbyl esters; Butylated hydroxyanisole; Butylated hydroxytoluene; Calcium ascorbate; Citric Acid; Citric and fatty acid esters of glycerol; Erythorbic acid (isoascorbic acid); Ethylene diamine tetra acetates; Guaiacresin; Isopropyl citrate; Nitrous oxide; Phosphoric acid; Potassium lactate; Propyl gallate; Sodium ascorbate; Sodium erythorbate (sodium isoascorbate); Sodium lactate; Stannous chloride; Stearyl citrate; Sulfites; Tartrates; Tertiary butylhydroquinone; Thioldipropionates; Tocopherols;
5 Bulking agent	Hydroxypropyl methyl cellulose; Mannitol; Methyl cellulose; Microcrystalline cellulose (cellulose gel); Polydextrans; Powdered cellulose; Processed Eucheama sea weed (PES); Propylene glycol alginate; Sodium alginate; Sodium carboxymethyl cellulose (cellulose gum); Sodium lactate; Carbon dioxide;
6 Carbonating agent	Carbon dioxide;
7 Carrier	Castor oil; Cyclodextrin, Beta-; Dextrins, roasted starch; Gum Arabic (Acacia gum); Magnesium hydroxide carbonate; Polyethylene glycol; Processed Eucheama sea weed (PES); Silicon dioxide, amorphous;
8 Colour	Allura red AC; Amaranth; Annatto extracts, Beta-based; Annatto extracts, Norbixin-based; Aurubine (Garmaisine); Brilliant black (Black PN); Brilliant blue FCF; Brown HT; Canthaxanthin; Caramel I – Plain caramel; Caramel II – Sulfite caramel; Caramel III – Ammonia caramel; Caramel IV – Sulfite ammonia caramel; Carmine; Carotenes, Beta-, vegetable; Carotenoids; Chlorophylls and Chlorophyllins, copper complexes; Curcumin; Erythrosine; Fast green FCF; Grape skin extract; Indigotine (Indigo Carmine); Iron oxides; Lutein from tagetes erecta; Ponceau 4R (Cochineal red A); Riboflavin; Sunset yellow FCF; Tartrazine; Xanthanin, synthetic
9 Colour retention agent	Aluminum ammonium sulfate; Ethylene diamine tetra acetates; Ferrous gluconate; ferrous lactate; Magnesium Carbonate; Magnesium chloride; Magnesium hydroxide; Magnesium hydroxide carbonate; Nitrites; Stannous chloride;
10 Emulsifier	Acetic and fatty acid esters of glycerol; Agar; Alginate acid; Ammonium alginate; Ammonium salts of phosphatidic acid; Beeswax; Candelilla wax; Carob bean gum; Carrageenan; Castor oil; Citric and fatty acid esters of glycerol; Dextrins, roasted starch; Diacetyltartaric and fatty acid esters of glycerol; Dioctyl sodium sulfosuccinate; Glycerol ester of wood rosin; Guar gum; Gum Arabic (Acacia gum); Hydroxypropyl cellulose; Hydroxypropyl starch; Karaya gum; Konjac flour; Lactic and fatty acid esters of glycerol; Lecithin; Methyl cellulose; Methyl ethyl cellulose; Microcrystalline cellulose (cellulose gel); Mono- and di-glycerides of fatty acids; Monostarch phosphate; Oxidized starch; Pectins; Phosphated distarch phosphate; Sodium dihydrogen phosphate; Trisodium phosphate; Phosphates; Polyethylene glycol; Polyglycerol esters of fatty acids; Polyglycerol esters of interesterified ricinoleic acid; Polyoxyethylene stearates; Polysorbates; Polyvinylpyrrolidone; Potassium alginate; Powdered cellulose; Processed Eucheama sea weed (PES); Propylene glycol; Propylene glycol alginate; Propylene glycol esters of fatty acids; Salts of myristic, palmitic and stearic acids with ammonia, calcium, potassium and sodium; Salts of oleic acid with calcium, potassium and sodium; Sodium alginate; Sodium aluminum phosphates; Sodium dihydrogen citrate; Sodium lactate; Sorbitan esters of fatty acids; Starch acetate; Starch sodium octenyl succinate; Starches, enzyme treated; Stearoyl lactylates; Stearyl citrate; Sucroglycerides; Sucrose acetate isobutyrate; Sucrose esters of fatty acids; Sucrose oligoesters, type I and type II; Tragacanth gum; Trisodium citrate; Xanthan gum;
11 Emulsifying salt	Sodium dihydrogen phosphate; Phosphates; Potassium dihydrogen citrate; Sodium aluminum phosphates; Sodium lactate; Tripotassium citrate; Trisodium citrate;
12 Firming agent	Aluminum ammonium sulfate; Calcium chloride; Calcium hydroxide; Calcium lactate; Calcium sulfate; Curdlan; Magnesium sulfate; Phosphates; Potassium chloride; Tricalcium citrate;
13 Flavor enhancer	Benzoyl peroxide; Calcium 5'-guanylate; Calcium 5'-inosinate; Calcium 5'-ribonucleotides; Calcium di-L-glutamate; Dipotassium 5'-guanylate; Disodium 5'-guanylate; Disodium 5'-inosinate; Disodium 5'-ribonucleotides; Ethyl maltol; Glutamic acid, L (+); Guanylic acid, 5'; Inosinic acid, 5'; Magnesium di-L-glutamate; Magnesium sulfate; Maltol; Monoammonium L-glutamate; Monopotassium L-glutamate; Monosodium L-glutamate; Neotame; Potassium 5'-inosinate; Sulfites; Tartrates;
14 Flour treatment agent	Alpha amylase from <i>Aspergillus oryzae</i> var.; Alpha amylase from <i>Bacillus subtilis</i> ; Azodicarbonamide; Benzoyl peroxide; Bromelain; Calcium lactate; Calcium oxide; Calcium sulfate; Carbohydrase from <i>Bacillus licheniformis</i> ; Chlorine; Citric and fatty acid esters of glycerol; Phosphates; Polysorbates; Sulfites;
15 Foaming agent	Ammonium alginate; Calcium alginate; Carbon dioxide; Methyl ethyl cellulose; Microcrystalline cellulose (cellulose gel); Nitrogen; Nitrous oxide; Polysorbates; Sucrose esters of fatty acids; Xanthan gum;
16 Gelling agent	Agar; Alginate acid; Ammonium alginate; Calcium alginate; Carrageenan; Curdlan; Konjac flour; Pectins; Potassium alginate; Processed Eucheama sea weed (PES); Sodium alginate; Sodium carboxymethyl cellulose (cellulose gum); Tara gum;
17 Glazing agent	Beeswax; Candelilla wax; Carnauba wax; Carrageenan; Castor oil; Gum Arabic (Acacia gum); Hydrogenated poly-1-decenes; Konjac flour; Microcrystalline wax; Mineral oil, high viscosity; Mineral oil, medium viscosity; Polyethylene glycol; Polyvinyl alcohol; Polyvinylpyrrolidone; Processed Eucheama sea weed (PES); Propylene glycol; Pullulan; Shellac, bleached; Sucrose esters of fatty acids; Sucrose oligoesters, type I and type II; Talk;
18 Humectant	Glycerol; Mannitol; Sodium dihydrogen phosphate; Trisodium phosphate; Phosphates; Polydextrans; Processed Eucheama sea weed (PES); Propylene glycol; Sodium DL-malate; Sodium lactate;
19 Preservative	Benzoates; Calcium acetate; Calcium propionate; Carbon dioxide; Dimethyl dicarbonate; Ethylene diamine tetra acetates; Hexamethylene tetramine; Hydroxybenzoates, para; Isopropyl citrates; Lauric arginate ethyl ester; Lysozyme; Natamycin (Pimaricin); Nisin; Nitrites; Ortho-phenylphenols; Trisodium phosphate; Potassium acetate; Propionic acid; Sodium acetate; Sodium diacetate; Sorbates; Sulfites;
20 Propellant	Carbon dioxide; Nitrogen; Nitrous oxide;
21 Raising agent	Ammonium carbonate; Ammonium hydrogen carbonate; Glucono delta-lactone; Sodium dihydrogen phosphate; Phosphates; Sodium aluminum phosphates; Sodium carbonate; Sodium hydrogen carbonate; Sodium sesquicarbonate;
22 Sequestrant	Calcium sulfate; Citric Acid; Citric and fatty acid esters of glycerol; Diacetyltartaric and fatty acid esters of glycerol; Ethylene diamine tetra acetates; Glucono delta-lactone; Isopropyl citrates; Lactic and fatty acid esters of glycerol; Phosphoric acid; Sodium dihydrogen phosphate; Trisodium phosphate; Potassium dihydrogen citrate; Sodium acetate; Sodium diacetate; Sodium dihydrogen citrate; Sodium gluconate; Stearyl citrate; Tartrates; Tricalcium citrate; Triethyl citrate; Tri-potassium citrate; Trisodium citrate;
23 Stabilizer	

(continued on next page)

Table 1 (continued)

Class	Additives
24 Sweetener	Acetylated distarch adipate; Acetylated distarch phosphate; Acetylated oxidized starch; Acid-treated starch; Agar; Alginate; Alkaline treated starch; Aluminium ammonium sulfate; Ammonium alginate; Beeswax; Bleached starch; Calcium alginate; Calcium chloride; Carob bean gum; Citric and fatty acid esters of glycerol; Curdlan; Cyclodextrin, Beta-; Dextrins, roasted starch; Diacetyltartaric and fatty acid esters of glycerol; Ethylene diamine tetra acetate; Glycerol ester of wood rosin; Guar gum; Gum Arabic (Acacia gum); Hydroxypropyl cellulose; Hydroxypropyl distarch phosphate; Hydroxypropyl methyl cellulose; Hydroxypropyl starch; Karaya gum; Konjac flour; Lactic and fatty acid esters of glycerol; Magnesium chloride; Mannitol; Methyl cellulose; Methyl ethyl cellulose; Microcrystalline cellulose (cellulose gel); Mono- and di-glycerides of fatty acids; Mono starch phosphate; Oxidized starch; Pectins; Phosphated distarch phosphate; Sodium dihydrogen phosphate; Trisodium phosphate; Phosphates; Polydextroses; Polyglycerol esters of fatty acids; Polysorbates; Polyvinylpyrrolidone; Potassium alginate; Potassium carbonate; Potassium chloride; Potassium dihydrogen citrate; Potassium hydrogen carbonate; Powdered cellulose; Processed Euchema sea weed (PES); Propylene glycol alginate; Salts of myristic, palmitic and stearic acids with ammonia, calcium, potassium and sodium; Salts of oleic acid with calcium, potassium and sodium; Sodium alginate; Sodium aluminium phosphates; Sodium carbonate; Sodium carboxymethyl cellulose (cellulose gum); Sodium dihydrogen citrate; Sodium hydrogen carbonate; Sorbitan esters of fatty acids; Starch acetate; Starch sodium octenyl succinate; Starches, enzyme treated; Stearoyl lactylates; Sucrose acetate isobutyrate; Sucrose esters of fatty acids; Sucrose oligoesters, type I and type II; Tara gum; Tartrates; Tragacanth gum; Triethyl citrate; Tripotassium citrate; Trisodium citrate; Xanthan gum
25 Thickener	Acetylated distarch adipate; Acetylated distarch phosphate; Acetylated oxidized starch; Acid-treated starch; Agar; Alginate; Alkaline treated starch; Ammonium alginate; Bleached starch; Calcium alginate; Candellilla wax; Carob bean gum; Carrageenan; Curdlan; Cyclodextrin, Beta-; Dextrins, roasted starch; Distarch phosphate; Glycerol; Guar gum; Gum Arabic (Acacia gum); Hydroxypropyl cellulose; Hydroxypropyl distarch phosphate; Hydroxypropyl methyl cellulose; Hydroxypropyl starch; Karaya gum; Konjac flour; Mannitol; Methyl cellulose; Methyl ethyl cellulose; Microcrystalline cellulose (cellulose gel); Monostarch phosphate; Oxidized starch; Pectins; Phosphated distarch phosphate; Sodium dihydrogen phosphate; Trisodium phosphate; Phosphates; Polydextroses; Polyethylene glycol; Polyvinyl alcohol; Polyvinylpyrrolidone; Potassium alginate; Potassium chloride; Powdered cellulose; Processed Euchema sea weed (PES); Propylene glycol alginate; Pullulan; Sodium alginate; Sodium aluminium phosphates; Sodium carboxymethyl cellulose (cellulose gum); Sodium lactate; Starch acetate; Starch sodium octenyl succinate; Starches, enzyme treated; Talc; Tara gum; Tragacanth gum; Xanthan gum

properties. Moreover, some food and food ingredients in powder form can absorb moisture readily when exposed to relative humidity change, and become sticky, agglomerate and form lumps, potentially leading to problems in food processing and storage (Figura & Teixeira, 2007).

Consequently, the food industries use anticaking agents, which are added in the production of dried powdered foods, salt, sugar confections and whey cheese products, among others. The most common anticaking agents are calcium and magnesium carbonates, phosphates and silicates. These are high water-binding agents that prevent caking by selectively binding the water and, notably, do not interfere with the final appearance of foodstuffs (Blekas, 2016).

2.1.3. Antifoaming agents

Fermentation processes can often present an undesirable foam appearance because of the presence of surfactants in the fermentation steps. Hence, the addition of antifoaming agents is necessary to produce a barrier that reduces the oxygen transfer rate and, consequently, decreases the foam production. In practice, the antifoaming agent destabilises the liquid film that covers the air bubble, displacing the substances from the surface, and thereby preventing the foam stability. Besides, the antifoaming agent can interact with the surface-active stabilisers, promoting the collapse of the liquid film and destabilising the foam, or by dilution of the antifoaming agent in the mixture (McClure, Lamy, Black, Kavanagh, & Barton, 2017).

The inadequate use of antifoaming agents decreases the shelf life of the foodstuffs so their use should be controlled. The fatty acid esters, polyesters and silicone-based oils/emulsions are the most common antifoaming agents applied to food products and beverages (Msagati, 2012).

2.1.4. Antioxidants

Oxidation by molecular oxygen is the main degradation process in foodstuffs and occurs as a consequence of the removal of electrons from a substrate (typically, oxygen-, nitrogen- or sulphur-containing) to an atom of oxygen present in the moisture, which gives rise to free radicals. Free radicals are highly reactive towards other molecules, due to their unpaired electrons, thereby leading to chain reactions. These reactions promote loss of the nutritional value and produce an undesirable flavour and smell. The initial step of the reaction is thermodynamically unfavourable, so the production of the first few radicals

necessary to initiate the propagation step requires the presence of a catalyst (e.g., light, metal ions, heat). To avoid or decrease the velocity of these reactions, the food industries add antioxidants, which interact with the free radicals and oxygen, responsible for promoting oxidation reactions in vitamins, natural colours and lipid components (Damodaran & Parkin, 2017).

Some substances naturally found in food (tocopherol and carotene) present antioxidant activity and contribute health benefits to industrialised foodstuffs. All synthetic antioxidants present chemical structures similar to natural phenolic compounds, which participate in the oxidation reactions through resonance-stabilised free radical forms. The main synthetic compounds are butylated hydroxyanisole, butylated hydroxytoluene and tertiary butylhydroquinone (Belitz et al., 2009). However, such synthetic antioxidants are not preferred due to toxicological concerns. Thus, increasing interest is focussed on identifying plant extracts as sources of antioxidants.

The application of antioxidants in foodstuffs increases the shelf life. However, their use must be carefully assessed and monitored, due to toxicity or inadequate concentrations, resulting in the formation of toxic compounds in foods that can be absorbed by the consumer and may cause health issues, such as degenerative diseases and mutations (Shibamoto & Bjeldanes, 2004). Furthermore, the inappropriate use of antioxidants can provoke unpleasant alterations in the flavour and aroma of the foodstuffs. The antioxidant efficiency is increased by the synergism among antioxidants; two or more antioxidants with different mechanisms (e.g., a combination of metal chelators and free radical scavengers), two or more free radical scavengers, whereby one of these substances is regenerated by others (e.g., the ascorbic acid/tocopherols system), protective action of one antioxidant that undergoes oxidation to shield the more effective antioxidant against oxidation (the interaction between carotenoids and tocopherols partly results from this mechanism) (Msagati, 2012). Table 1 lists the main antioxidants used by the food industries.

2.1.5. Bulking agents

The volume is an important characteristic of foodstuffs since it contributes to a fundamental sensorial attribute, the texture. In the food industries, bulking agents are used to increase and stabilise the final volume of the feedstock and foodstuffs during the processing and storage. Frequently, the addition of sugars to the bulk contributes

significantly to the final volume. When moisturised with fat, it allows trapping air in its crystals, and when moisturised with flour, competes with gluten for water and dissipates the molecules of this protein. Both actions result in the enhanced lightness of the mass, improving its texture.

However, the need for low-calorie products has promoted the increased use of sweeteners, which do not help to give volume to the mass. Hence, the bulking agents are added to solid and semi-liquid foods, to increase the final products volume, without affecting the taste or contributing to the energetic final value of foodstuffs. Mannitol, methylcellulose, microcrystalline cellulose and polydextrose are some common bulking agents introduced into foods.

2.1.6. Carbonation agents

The carbonation of beer, fruit juice, wine and soft drinks improves the tactual perception and provides slight acidity, a tangy taste and effervescence to these beverages. For this, carbon dioxide is added, according to the necessity of the industrial process and specific legislation. Carbonation is usually conducted at high pressure and low temperature to improve carbon dioxide solubility. Furthermore, the retention of substantial quantities of carbon dioxide in solutions at atmospheric pressure is attributed to surface adsorption by colloids and chemical ligations/interactions. The adequate setting of the carbonation parameters is important in the quantity of carbon dioxide liberated in industrial beverages and can be indicative of inferior quality (Damodaran & Parkin, 2017).

2.1.7. Carriers

Some food additives can present low solubility or undesirable stability, interfering in its function and consequentially in the final quality and safety of foodstuffs. Compounds that aid in the dissolution, dilution, dispersion or physical modifications of a food additive, without modifying its technological properties are termed carriers, and their use facilitates the handling and application of food additives, such as flavouring and antifoaming agents. Some vegetable and minerals oils are commonly used as carriers in food processing (Msagati, 2012).

2.1.8. Clarifying and appearance control agents

Turbidity and colour are important characteristics related to consumer acceptance of beverages, so the beverage industries employ certain additives to control these attributes. These compounds act to slow down the sedimentation of solids, change the viscosity and density, and disperse the flavouring by oil compounds, so they are referred to as appearance control additives (Damodaran & Parkin, 2017).

Clarifying agents are commonly added to improve the appearance of some beverages, such as fruit juice, beer and wine, by removing suspended particles or precipitates and preventing oxidative reactions, which are long-standing issues. Nonetheless, nonselective clarifiers can cause undesirable effects during the manipulation and can accidentally modify the content of the polyphenolic substances. Bentonite and montmorillonite clays are clarifying agents primarily used in wine due to their selectivity to preclude protein precipitation.

Polyamides and polyvinylpyrrolidone remove compounds that produce undesired flavour in beer. Some types of gelatine remove tannins, proanthocyanins and other polyphenols that compromise the quality of beverages (Belitz *et al.*, 2009). Despite intensive use by the food industries, clarifying and appearance control agents are not considered among the chemical classes established by the *Codex Alimentarius* (FAO/WHO, 2016).

2.1.9. Colours

The first characteristic of foodstuffs evaluated by consumers is the colour, which is related to the foodstuffs quality and directly influences the perception of flavour and sweetness. Moreover, undesirable colour modifications during the processing and storage of foodstuffs can be affected by many factors, such as the presence or absence of oxygen,

metals, light, oxidation reactions, pH and water activity. To overcome this issue, chemical compounds that impact colour, are intensively used by the food industries (Damodaran & Parkin, 2017).

The colours can be natural compounds, termed pigments, derived from the cells of animal and plant tissues. These colours do not cause a residual taste when added in sufficient concentration, and the health benefits of natural pigments, like carotenoids, carotenes, riboflavins, chlorophylls, betalains and other natural colours have been demonstrated (Msagati, 2012).

However, artificial colours are preferred by the food industries due to their stability, ease of handling during the processing of the foodstuff and control over the intensity of the colourant and thereby low cost. Table 1 presents the main colours used as food additives. Ponceau 4R, sunset yellow and amaranth, are sorely used, and in some countries, their use is banned due to the promotion of diseases after accumulation in human organisms, similar to some other synthetic colours (Shibamoto & Bjeldanes, 2004).

2.1.10. Colour retention agents

Appearance is the most important parameter evaluated by consumers before deciding whether to purchase the food. As mentioned in Section 2.1.9, the colour of the foodstuffs directly influences the perception of the freshness and food safety. Colour retention agents, like ferrous lactate, magnesium carbonate and magnesium hydroxide, play a crucial role in stabilising, preserving or intensifying the original food colour throughout the processing and storage (Msagati, 2012). Besides, the red appearance of meat products is improved by the addition of nitrates (FAO/WHO, 2017).

2.1.11. Emulsifiers

The permanence of the sensorial, physicochemical and rheological properties of the foodstuffs is ensured by the use of emulsifiers, which provide a uniform dispersion between the dispersed phase (droplets) and continuous (bulk) phase, promoting a stable heterogeneous system, such as water and oil mixtures. Emulsifiers encourage stability, increase shelf life, control rancidity reactions, viscosity and texture, and the polymorphism and crystalline structure of fats, solubilise flavours and inhibit phase separation in foodstuffs, improving the acceptance of the industrialised products by consumers (Damodaran & Parkin, 2017).

The main emulsifiers used are the mono- and diacylglycerides and their derivatives, which correspond to around 75% of the emulsifiers worldwide. Many compounds (e.g., tartaric acid, succinic anhydride, ethylene oxide, citric acid) can be reacted with mono- and diglycerides of edible fatty acids to form new emulsifiers with different functions. Mono and diacetyl tartaric acid esters of mono- and diglycerides, for example, are used as dough conditioners in baked products, particularly, white bread, rolls and in flour mixes for convenience food. In chocolate production, emulsifiers are added to avoid defects in the appearance, such as phase separation that can occur (Belitz *et al.*, 2009).

2.1.12. Firming agents

The firmness and texture of processed products are industrially ensured through the use of firming agents that stabilise the cellular structure of fruits and vegetables. These rheological properties are maintained during the processing, independent of the temperature variation, using firming agents in sufficient concentration and inhibit the formation of a bitter flavour (Damodaran & Parkin, 2017).

Calcium salts, such as chloride, citrate, sulphate, lactate and phosphate, are commonly used to improve the effects of hardening before canning and freezing fruits and vegetables. Pectin and pectic acid remain in the cell wall during the heating of the fruits and vegetables due to the presence of firming agents added during the industrial process. This functionality can be improved by the combination of calcium and aluminium salts. In general, the efficiency of firming agents depends on the medium pH that is controlled by acetic and lactic acid additions (Belitz *et al.*, 2009).

2.1.13. Flavour enhancers

Sometimes it is necessary to intensify the flavour of foodstuffs to increase consumer acceptance. Improving the flavour perception at the molecule receptor level consequently promotes the alterations of the functions or neural systems feelings. For this purpose, flavour enhancers are added to foodstuffs during the processing steps (Belitz *et al.*, 2009) to improve the palatability, characterised by sensorial parameters, such as complexity, fullness, body, food flavour, thickness and continuity. The use of flavour enhancers can also contribute to smell, improve the perception of softness, juicy and creaminess (Damodaran & Parkin, 2017).

Monosodium glutamate is the most known flavour enhancer, which promotes the sensory perception of the meat-like aroma notes in frozen, dehydrated or canned fish and meat products. However, in sensitive consumers, monosodium glutamate causes undesirable disorders, such as temporary drowsiness, headache, stomach ache and stiffening of the joints (Msagati, 2012).

The synthetic flavour enhancers, maltol and ethyl maltol, are often present in candy and foodstuffs produced from fruits, due to their ability to promote high softness and enhance sweetness. The nucleotides, such as 5'-inosine monophosphate and 5'-guanosine monophosphate are used as flavour enhancers in soups, sauces, canned meat and tomato juices, attributed to providing an increased viscosity of liquid foods and the sensations of freshness and naturalness (Belitz *et al.*, 2009). Other flavour enhancers are shown in Table 1.

2.1.14. Flour treatment and bleaching agents

Chemical compounds are frequently used by the flour industries to accelerate the maturation and ageing of flour, thereby improving the fermentation process and the appearance of the flour products. These substances are classified as flour treatment and bleaching agents, which promote the oxidative degradation of carotenoid pigments, by conversion to free radicals. The manipulation of the flour of pasta is facilitated through enzymatic inhibition and pH control, leading to an improvement in the flour colour and the texture of the flour products (Damodaran & Parkin, 2017).

Some flour treatments agents include ethyl maltol, disodium 5'-guanylate, disodium 5'-inosinate, guanylin acid, glutamic acid and others. Bleaching agents, like sulphites and benzoyl peroxides, improve the baking of the flour products without changing the colour of the foodstuffs (Msagati, 2012).

2.1.15. Foaming agents

Some foodstuffs present foam in their physical structure to promote the aeration, improving the dispersion of the molecules and favouring the consumers' acceptance by further refining the sensorial characteristics. The food industries employ food additives, classified as foaming agents, in the stabilisation of the foams produced in the manufacturing steps, which are a prerequisite in the quality control of various foodstuffs (Green, Littlejohn, Hooley, & Cox, 2013).

Research has demonstrated that the chemical interactions between foaming agents and the components of the foodstuffs enrich the sensory quality of the products (Green *et al.*, 2013). The interaction between the foam structure and the capacity of the foaming agent in the maintenance of this structure can be considerable in industrial processes. Hydrocolloids (gelatine and ovalbumin) are the most common foaming agents added during the processing of beers, ice creams, bread and emulsions. However, because these compounds originate from animal sources, they are rejected by some consumers, indicating the importance of developing alternatives with suitable quality and food security.

2.1.16. Gelling agents

The gelling agents are a class of food additives used to promote gel formation, which is a viscoelastic semisolid that presents elastic solid and viscous liquid characteristics. The use of gelling agents produces a

three-dimensional physical structure, improving the homogeneity in the foodstuff. The gelling agents produce a gel with suitable stability, which can be a quality indicator, and act in the processing steps to enrich the viscosity of the final products (Belitz *et al.*, 2009).

Hydrocolloids, often called gums, function as structuring/gelling agents via the involvement of specific inter-chain associations in conformationally ordered junction zones, which form the basis for the three-dimensional network characteristic of a gel. The physical arrangement of these junction zones is dependent on the pH, interest rheology, processing temperature, texture, quantity of gelling agents, interactions between the ingredients and the functional characteristics. The gums act as cloud agents, coating agents/film formers, clarifying agents, crystallisation and syneresis inhibitors, suspension stabilisers, binders, whipping agents, swelling agents, mould release agents, foam stabilisers, flocculating agents, fat mimetics, encapsulating agents, emulsion stabilisers, bulking agents, binders and bodying agents (Damodaran & Parkin, 2017).

The aligins, carboxymethyl-cellulose, carrageenan, pectin, alginate, xanthan and others, shown in Table 1, are the most common gelling agents used by the food industries. The types and the quantity used are defined by the specific legislation, according to each country (Msagati, 2012).

2.1.17. Glazing agents

The appearance of some foodstuffs can become more attractive, when they look brighter, such as fruit and vegetable candies. Providing a brighter exterior and protection to the external surface of foodstuffs can be achieved by the addition of glazing agents during the manufacturing process. The protective outer coating provided by some glazing agents, such as the waxes in apple peel, can also increase the shelf life of some fruits and vegetables (FAO/WHO, 2017).

In industrial processes, the most common glazing agents used are beeswax, candelilla wax, carnauba wax, castor oil and polyethylene glycol, among others shown in Table 1.

2.1.18. Humectants

During the transport and storage, some foodstuffs can lose moisture, decreasing the shelf life and damaging the appearance of the product. In general, the loss of moisture affects the final texture and, consequently, sensorial perception, attributed to the unpleasant dryness or hardening of the food experienced by the consumers. To avoid this problem, humectants, i.e., substances that protect foods from the moisture loss, may be used in the formulation of foods susceptible to dryness. Glycerol, mannitol, polydextrose and propylene glycol are humectants employed in the fabrication of sweets, bread, cake and biscuit fillings, chocolates and other products (Msagati, 2012).

2.1.19. Preservatives/antimicrobial agents

The prevention of the spoilage and assurance of the safety of food can be obtained by use of compounds that act as preservatives of foodstuffs, by presenting antimicrobial properties, preventing the degradation by enzymatic and non-enzymatic reactions. Its realisation depends on some conditions, such as the pH and solubility of the food. The use of preservatives/antimicrobial agents increases the shelf life of the foodstuffs, but at high concentrations, these compounds can promote an unpleasant taste, intense odour, change in viscosity and colour retention, and decrease in the solubility (Msagati, 2012).

The food industries employ preservatives/antimicrobial agents, which can be used to inhibit non-enzymatic browning and enzyme-catalysed reactions, and the reversible cleavage of proteins (sulphites and sulphur dioxide). In the meat industries, the sodium and potassium salts of nitrite and nitrate are often used to preserve cured meat and sausages. In the production of bread and baked goods, the acetates of sodium, potassium and calcium, and propionic acid were incorporated to prevent the growth of moulds, thereby increasing the shelf life of these foodstuffs. Other compounds used for this purpose are benzoate,

sorbate, epoxides, glycerol esters, and diethyl pyrocarbonate (Belitz et al., 2009).

Some antibiotics are used as food preservations, but their use must be adequately evaluated, as the consumption of food treated with antibiotics may cause sensitisation of the consumer to the antibiotics used and may result in the emergence of antibiotic-resistant microorganisms. In the cheese and yoghurt industries, the inhibition of undesirable bacteria, yeasts and fungi is realised by the use of preservatives, such as benzoates, sorbates, natamycin (an antibiotic) and *Lactobacillus*, which maintain the quality of products and improve the nutritional quality, respectively (Damodaran & Parkin, 2017).

2.1.20. Propellants

Some foodstuffs are physically presented as sprays, foams and liquids. The stabilisation of these forms is a huge challenge in the food industries. Pressurised aerosols, called propellants, promote the expansion of the foodstuffs and are in intimate contact with the food, and therefore, are considered as food additives. Propellants are classified according to their physical state (liquids and gaseous compounds), and their use depends on the food physicochemical property's needs (Damodaran & Parkin, 2017).

Gaseous propellants are non-toxic, do not promote undesirable flavour and colour, are non-flammable and present low cost. The most common gaseous propellants are nitrous oxide and carbon dioxide, employed in systems where foams and sprays are desired, due to their water solubility and suitable expansion in closed systems. Carbon dioxide is used in products where the tanginess and tartness are necessary, such as in cheese. Nitrogen is used in ketchup, edible oils and syrups, in which the foaming can be avoided (Belitz et al., 2009).

The main liquid propellants used in vegetable oils and emulsified products are octafluorocyclobutane and chloropentafluoroethane. These compounds present low flammability, are non-toxic in low concentrations and do not interfere with the flavours of the foodstuffs. Other chlorofluorocarbon compounds are prohibited, as they are environmentally toxic, promoting degradation of the ozone layer in the atmosphere (Msagati, 2012).

2.1.21. Raising agents

Raising agents or chemical leavening systems are compounds added to foodstuffs to promote the expansion of the dough or batter, improving the texture, softness and flavour. The use of raising agents fosters the release of carbon dioxide and the expansion of pasta, which is dependent on the concentration and temperature of paste, that interfere directly in the characteristic of the foodstuffs based on baking mixes, household, self-rising flours, commercial baking powder and dough products (Damodaran & Parkin, 2017).

The more common raising agents contain bicarbonate salt and carbonate that are soluble in water, promoting complete ionisation of carbonate and release of carbon dioxide. The dough or batter are complex systems, containing proteins and other natural compounds that can participate in the chemical reactions of the raising agents, avoiding the appearance of undesirable flavour in the foodstuffs and assisting in the end pH stabilisation. Other salt acids used as raising agents are potassium acid tartrate, sodium aluminium sulphate, δ -gluconolactone and acid pyrophosphate, which produce gas due to specific enzyme actions (Msagati, 2012).

2.1.22. Sequestrates/chelating agents

Sequestrants or chelating agents are chemical compounds used as stabilisers of foodstuffs, through complexation of metals ions that catalyse hydrolytic reactions and degradations process. Metals interfere in foodstuffs, modifying the flavour, smell and colours and, consequently, promote alterations in the final product stability. Some natural compounds present in the feedstocks act as sequestrants or chelating agents, such as chlorophyll that complexes with magnesium; ascorbic acid that complexes iron to improve its ingestion; some enzymes that complex

copper and zinc; and some proteins that complex iron, among others (Belitz et al., 2009).

In industrial processes, the sequestrant or chelating agents employed are chemical compounds that present the functional groups $-NR_2$, $-S-$, $-OH$, $-SH$, $-O-$, $C=O$, $-COOH$ and $H_2PO_3^-$, which have an unshared pair of electrons that can react with metals ions. The complexation reactions depend on the pH of the medium. Polyphosphates and ethylene diamine tetra-acetic (EDTA) salts can be used in canned seafood to prevent the formation of glassy crystals, and in vegetables and fruits to inhibit the discolouration reactions. Some acidulate also act as sequestrants or chelating agents, such as citric acid and phosphoric acid, used in the soft drinks industries (Damodaran & Parkin, 2017). The EDTA salts are the most used sequestrants employed by the food industries, but their use requires rigorous control due to a capacity to complex with metals naturally present in humans. The inadequate ingestion of certain minerals can promote serious diseases (Msagati, 2012).

2.1.23. Stabilisers

The food industries frequently use compounds to avoid phase separations, ensuring the homogeneity of foodstuffs. These compounds are classified as stabilisers, and their use is fundamental to ensuring a desirable sensorial attribute, particularly, in the stabilisation of emulsions and suspensions, to improve the texture by inhibiting the formation of crystals and increasing the viscosity, thereby enhancing the appearance of foodstuffs (Damodaran & Parkin, 2017).

Stabilisers are also utilised as thickener agents, gelling agents, suspending agents and glazing agents, as well as to control the fluidity and retention of water in diverse products. The properties of stabilisers are influenced by the pH, temperature, concentration, molecular weight and ionic forces. These foods additives are used in broths, desserts, sweets, preserves, ice creams, pasta, dairy products, processed foods, bakery, soups, biscuits, juices and chocolates. Examples of some common food stabilisers are alginate, carrageenan, casein, carboxymethylcellulose sodium salt, xanthan, guar and locust bean gum (Belitz et al., 2009).

2.1.24. Sweeteners

Sweeteners are chemical compounds used to intensify the sweetness and/or the perception of the sweet taste, directly influencing the acceptance of foodstuffs. Artificial or non-nutritive sweeteners are often used as a sugar alternative. These sweeteners are low in calories. Such compounds must demonstrate safety at the levels used in the food and have a low residual taste. Nutritive sweeteners (e.g., fructose, isomalt, sugar alcohols, maltodextrin) are based on different types of carbohydrates and have less energy than sugar, but they are not calorie-free. Sweeteners are chemically divided into sulphonamides, peptides, chlorosaccharides, low-calorie sweeteners and polyols (Damodaran & Parkin, 2017).

The sulphonamide sweeteners present a sulphamic acid group and comprise potassium acesulfame, cyclamates and saccharin. These compounds are up to 700 times sweeter than sucrose but cause a bitter and residual metal taste. Research about the toxicities of the sulphonamides are controversial, but an increased incidence of diseases attributed to the ingestion of these substances has not been proven (Shibamoto & Bjeldanes, 2004).

The peptide sweeteners present suitable sweetness at low concentrations and, consequently, their use promotes insignificant ingestion of calories. These compounds have a sweetness intensity of 200–13,000 times that of sucrose, without residual taste. Despite this, their use can promote alteration in the flavour of foodstuffs. Moreover, for some consumers, the use of these sweeteners can provoke health problems, such as allergies, heart diseases and phenylketonuria (Belitz et al., 2009).

The chlorosaccharide sweeteners present a more intense sweetness potency (600-fold) than sucrose (sugar) and are produced by selective

chlorination of the saccharide. These compounds have high crystallinity, no bitterness, and good solubility and stability at various temperatures (Msagati, 2012). The polyols are a chemical class that beyond sweetening, promote control of the texture, crystallisation and viscosity, humidity retention and diminution in the water activity, improving the softness and water rehydration properties of foodstuffs (Damodaran & Parkin, 2017).

2.1.25. Thickeners

In choosing foodstuffs, the consumer evaluates the texture and viscosity, which can influence the perception of the food quality either positively or negatively. In some foods, like ice cream, chocolate milk, cream cheese, mayonnaise and confectionery product coverings, high viscosity is desirable. Therefore, to obtain the necessary viscosity, the food industries add thickeners in the food processing steps. These added compounds are water-soluble and hydrophilic, being used to disperse, stabilise or prevent sedimentation of substances in suspensions. Gums, starches, pectins and others (Table 1) are most commonly used for this purpose.

3. Analysis of food additives

The use of food additives requires a rigorous food safety policy since some compounds can pose a risk to the consumers' health. Some researchers have shown that the cumulative consumption of food additives can provoke allergies, diabetes, obesity and metabolic disorders (Shibamoto & Bjeldanes, 2004). As a result, each country has specific legislation, encouraging a suitable quality control in industrialised foodstuffs, with the identification and quantification of food additives used or produced during the industrial process. Illegal food additives, used in some industries to mask the degradation process or inadequate manipulation procedures, also need careful monitoring.

Analytical techniques are used to identify and quantify different food additives in feedstocks, independent ingredients, the processed products and end-products, and in all intermediate compounds formed during the manufacturing process. Thus, it is necessary to implement techniques that provide reliability, selectivity, sensitivity, quickness, operational security and are environmentally friendly and, mainly, low cost, to use in quality control and evaluation of food safety (Wrolstad et al., 2005).

Regardless of the instrumental techniques (spectroscopic, chromatographic and electroanalytical) employed, the food additives analysis requires the adequate evaluation of the sampling and pre-treatment steps and the interpretation of the results, which are responsible for success in chemical analysis (Mitra, 2004). The strict sampling procedure is necessary to guarantee the representativeness of the food sample, by reflecting all its constituents and so obtaining reliability in the analytical results. In an ideal sampling procedure, the sample should be identical considering intrinsic properties from the raw materials, independent ingredients, the processed products or end-products analysis (Nollet & Toldrá, 2017).

To ensure the representativeness of the samples and, consequently, the reliability of the analytical results, the sampling protocol is optimised by statistic techniques. The sampling protocol depends on the size of the sample, variability of the sample components, cost of the analysis of each sample and, sometimes, depends on the specific legislation regulating the use and analysis of the food additives, indicating the procedures and minimum amount of the samples necessary in the chemical analysis (Nielsen, 2014).

The presence of fats, oils, lipids, proteins, carbohydrates, polysaccharide, salts, surfactants, pigments, emulsions and turbidity can interfere in the analysis of food additives. Hence, pre-treatment of the food samples is conducted before the chemical analysis, to remove as many interfering compounds as possible. The adequate choice of the sample preparation method is based on the nature of the food sample and in the analysis to be performed. Mixing, homogenisation, dilution, centrifugation, distillation, simple solvent extraction, supercritical fluid

extraction, pressurised-fluid extraction, microwave-assisted extraction, Soxhlet extraction and/or derivation, are some procedures effectuated as pre-treatments of food samples. These pre-treatments need to be rapid, simple, inexpensive and environmentally friendly (Wrolstad et al., 2005).

The use of microwave-assisted extraction as a pre-treatment method in high-performance liquid chromatography (HPLC) and near-infrared (NIR) analysis have been demonstrated enhanced recovery of food additives, limiting extraction time and solvent waste (Nescatelli et al., 2017). The employment of magnetic molecularly imprinted polymers for food additive analysis promote a less time-consuming pre-concentration procedure comparing to classical methods, with fast adsorption kinetics and selective adsorption capacity (Xu, Niu, Chen, Zhao, & Chen, 2017). Ultrasound-assisted extraction has been shown as a suitable pre-treatment method in the food additives analysis, due to the enhancement of the analytical responses attributed to cavitation and thermal effects of ultrasonication.

The analytical data in food analysis can be validated using statistical methods, ensuring reliability and analytical quality and adequacy to specify legislation. The linearity, accuracy, precision, sensitivity, range concentration, limit of detection, limit of quantitation and robustness are analytical parameters evaluated to demonstrate the analytical method employed is capable of identifying and quantifying the food additive, with reliability in complex samples and over a suitable range of concentrations (Wrolstad et al., 2005).

There are many analytical techniques available for the analysis of the food additives. The ultimate choice depends on the nature of the samples (solid, liquid or gas), expected level of the additive, the analyst's experience, the equipment and reagents available, the time of analysis, the number of samples and, mainly, the levels of interfering substances present in the samples.

Figs. 2–4 show the research realised during the last 10 years, to indicate the applicability of the spectroscopic, chromatographic and electroanalytical techniques, respectively, for the analysis of the 25 functional classes of food additives. Most of the published papers are related to the analysis of food additives that promote toxicities to the consumer and/or cause undesirable flavour in the foodstuffs, which are acidity regulators, colours, antioxidants and preservatives.

Each technique presented has a set of characteristics, allowing to identify and quantify the additive of interest, with advantages and disadvantages typical of the methodology used. The main analytical methods used in the analysis of the food additives in foodstuffs are classified in spectroscopic (Section 3.1), chromatographic (Section 3.2) and electroanalytical techniques (Section 3.3).

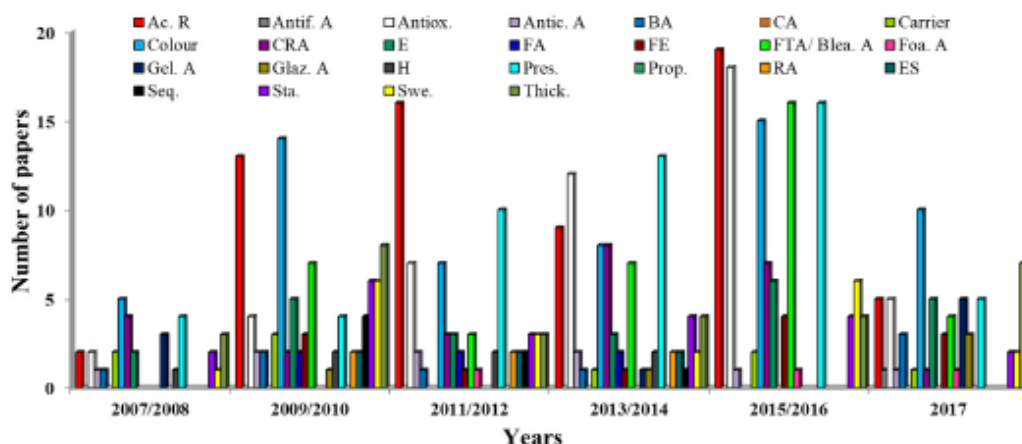
3.1. Spectroscopy techniques

The spectroscopy techniques are based on the interaction of electromagnetic radiation with the matter. The energy from heat, electric discharge or light promote the momentary excitation of the electrons to a state of greater energy (excited state), and when the electrons return to the initial energy status (fundamental states), energy is released, previously absorbed, in the light form. If the light intensity measured is higher than the added light on the sample occurs higher light emission (emission spectroscopy) and if the light intensity measured is lower than the added light on the sample occurs absorption and the measured intensity of light is lower (absorption spectroscopy) (Skoog, West, Holler, & Crouch, 2014).

Chemical structures of food additives present functional groups, allowing the absorption and/or emission of electromagnetic radiation at a known wavelength, which can be employed to quantify food additives in feedstocks and foodstuffs. The main methods employed by the food industries are ultraviolet/visible radiation (UV/Vis) spectroscopy and infrared spectroscopy (IR), which are used in determining the chemical composition, textural parameters and quality-related parameters (Wrolstad et al., 2005).

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Ac. R = Acidity Regulator; Antic. A = Anticaking Agent; Antif. A = Antifoaming Agent; Antiox. = Antioxidant; BA = Bulking Agent; CA = Carbonating Agent; CRA = Colour Retention Agent; E = Emulsifier; ES = Emulsifying Salt; FA = Firming Agent; FE = Flavour enhancer; Foa. A = Foaming Agent; Gel. A = Gelling Agent; Gla. A = Glazing Agent; H = Humectant; Pres. = Preservative; Prop. = Propellant; Seq. = Sequestrant; Swe. = Sweetener; Thick. = Thickeners;

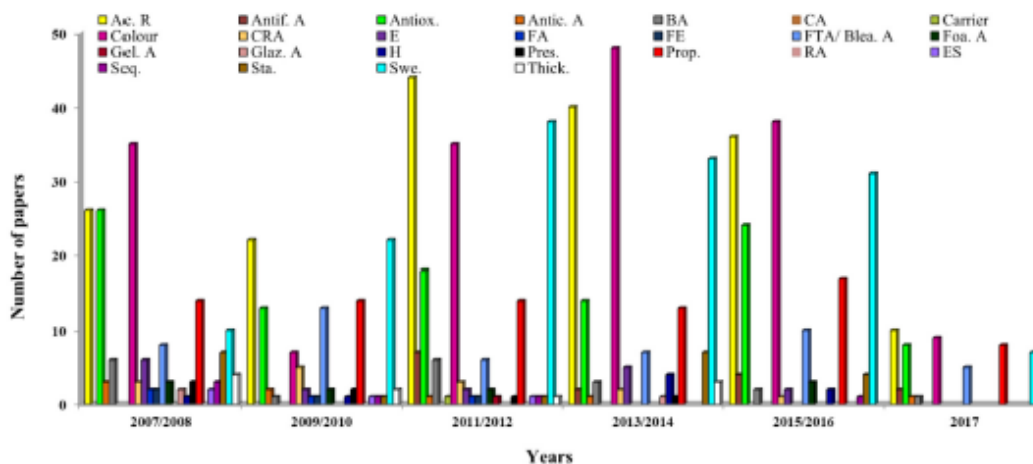
Fig. 2. Researches related to the analytical determinations of food additives in foodstuffs using spectroscopic methods, from 2007 to 2017 years.

The UV/Vis technique (from 190 to 800 nm wavelength) measures the fraction of radiation transmitted through the sample. Its instrumentation requires a source of electromagnetic radiation, a means of selecting the wavelength at which the transmittance is measured and a detector for measuring the transmittance. The transmittance is related to the absorbance and the concentration of the absorbing species, by Beer's law (Christian, Dasgupta, & Schug, 2014).

Use of UV/Vis in quality control is adequate in the determination of different food additives, attributed to its efficiency, low cost, non-destructive and environmentally friendly approach, and operational

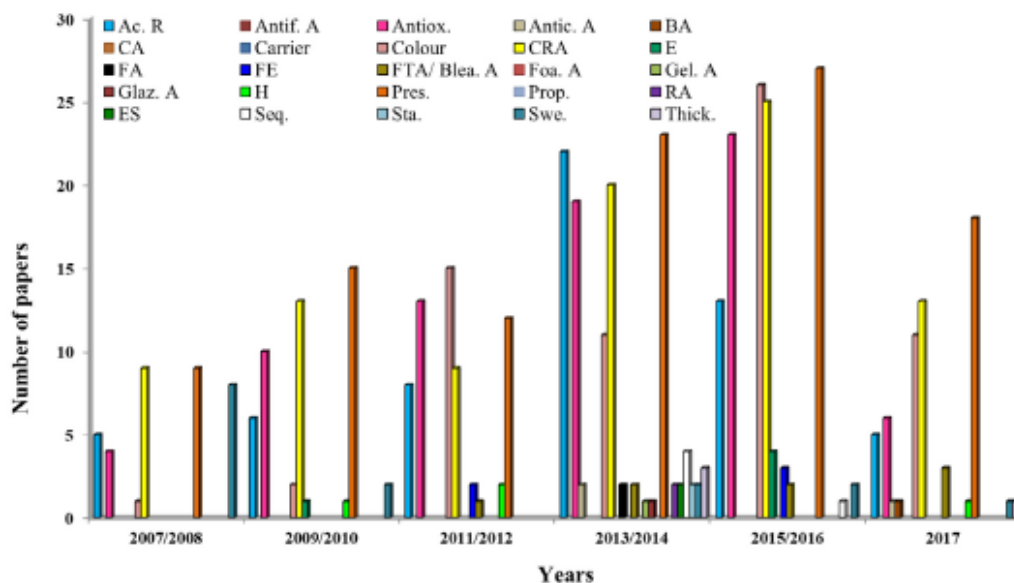
simplicity, and is considered suitable for online measurement. However, in foodstuffs analysis, the composition of the samples promotes an undesirable selectivity, due to the presence of other chemical compounds that absorb electromagnetic radiation. To overcome this issue, it is necessary to first treat the sample, for further analytical efficiency and selectivity (Skoog et al., 2014). The use of artificial neural network methods is used to model multicomponent absorbance data and improve the selectivity of food analysis by UV/Vis techniques (Esteki, Shahsavari, & Simal-Gandara, 2018; Santos & Schug, 2017).

In IR spectroscopy, the absorption of light by chemical compounds



Ac. R = Acidity Regulator; Antic. A = Anticaking Agent; Antif. A = Antifoaming Agent; Antiox. = Antioxidant; BA = Bulking Agent; CA = Carbonating Agent; CRA = Colour Retention Agent; E = Emulsifier; ES = Emulsifying Salt; FA = Firming Agent; FE = Flavour enhancer; Foa. A = Foaming Agent; Gel. A = Gelling Agent; Gla. A = Glazing Agent; H = Humectant; Pres. = Preservative; Prop. = Propellant; Seq. = Sequestrant; Swe. = Sweetener; Thick. = Thickeners;

Fig. 3. Researches related to the analytical determinations of food additives in foodstuffs using chromatographic methods, from 2007 to 2017 years.



Ac. R = Acidity Regulator; Antic. A = Anticaking Agent; Antif. A = Antifoaming Agent; Antiox. = Antioxidant; BA = Bulking Agent; CA = Carbonating Agent; CRA = Colour Retention Agent; E = Emulsifier; ES = Emulsifying Salt; FA = Firming Agent; FE = Flavour enhancer; Foa. A = Foaming Agent; Gel. A = Gelling Agent; Glaz. A = Glazing Agent; H = Humectant; Pres. = Preservative; Prop. = Propellant; Seq. = Sequestrant; Swe. = Sweetener; Thick. = Thickeners.

Fig. 4. Researches related to the analytical determinations of food additives in foodstuffs using electroanalytical methods, from 2007 to 2017 years.

promotes a change in vibrational energy levels, resulting in the absorption of IR radiation by different functional groups, at different frequencies of radiation. The absorption of radiation in the near-IR, from 0.8 to 2.5 μm wavelength, is useful for qualitative analysis, such as identifying specific functional groups present in substances while mid-IR, from 2.5 to 15 μm wavelength, is used in quantitative analysis. IR spectroscopy techniques are widely used to identify functional groups in solid, liquids and gaseous samples.

NIR uses a radiation source that provides intense radiation in the 0.8–1.75 μm range and a detector roughly 100 times more sensitive than other IR detectors. Hence, this technique is used most extensively for quantitative applications, either using transmission or diffuse reflection measurements that can be taken directly from solid foodstuffs. For this reason, NIR finds use in the analysis of feedstocks and final products, such as biscuits, muesli bars, ready-to-eat breakfast products, processed meat products, butter and margarine.

The NIR instrumentation uses multivariate statistical techniques and calibration steps to measure the quantities of various food additives in a variety of foodstuffs, based on the amount of IR radiation absorbed at specific wavelengths. Besides, the method performs rapid quantitative analysis, does not require hazardous reagents and no chemical waste is generated. However, the high initial cost of the instrumentation and the necessity of the specific calibrations for each product measured are the disadvantages of NIR spectroscopy in the food industries.

In Fourier transform infrared (FTIR) spectroscopy the instrumentation uses an interferometer. The radiation is not dispersed, but rather all wavelengths arrive at the detector simultaneously. The results are converted to give a typical IR spectrum of the absorbance vs frequency of the radiation, using the Fourier transformations as the mathematical procedure to improve the quality and interpretation of the analytical results, facilitating the use of IR in food quality control. This technique

provides a rapid and accurate data acquisition and is a non-destructive procedure. It also allows data analysis by a variety of software algorithms that have dramatically increased its practical use in the food industries (Babushkin, Spiridonov, & Kozhukhar, 2016). In addition, FTIR spectroscopy permits determining the concentration of each food constituent from the absorbance values at a selected wavelength, improving the selectivity in the food analysis. However, like NIR spectroscopy, the high initial cost of the instrumentation is the main drawback of FTIR in the food industries (Amir et al., 2013; Van de Voort, 1992).

Raman spectroscopy is a technique based on the scattering of light, where the frequency of a small fraction of scattered radiation is different from the frequency of monochromatic incident radiation in the sample. The Raman spectra are formed from the inelastic collision between incident monochromatic radiation and molecules of the sample and can be used for qualitative and quantitative purposes. The lasers used in Raman spectroscopy emit radiation in the near-IR wavelength, and the intensity of the scattered light is measured at different frequencies from the incident light. Raman spectroscopy is applicable to liquids and solid foodstuffs. The Raman analysis is quick and cheap, due to a simple preparation of the samples; however, the weak Raman scattering promotes a low analytical sensitivity (Bumrah & Sharma, 2016; Nielsen, 2014).

Fluorescence spectroscopy is a technique based on the emission of the electromagnetic radiation by chemical compounds when a molecule in the lowest vibrational energy level of an excited electronic state returns to a lower energy electronic state, by emitting a photon after the absorption of the light of a specific wavelength (Sádecká & Tóthová, 2007). The fluorescence spectra are formed by respective wavelengths for excitation and emission and will depend on the chemical structure of the target compound. Only chemical compounds that present rings and rigid chemical structures will emit electromagnetic radiation with

considerable intensity because these structures do not allow the release of the energy absorbed by paths other than the emission of light (Christian et al., 2014).

Fluorescence instrumentation is like UV/Vis spectroscopy, but the analytical results are 1–3 orders of magnitude more sensitive than UV/Vis. However, fluorescence is only used for rigid chemical structures analysis, and few compounds in food present these structures, decreasing the applicability of this technique in the food industries (Albani, 2012). The high selectivity of fluorescence is used as an accurate tool to monitor the molecular changes that occur during food handling, processing or storing of foodstuffs containing sweeteners, colours and emulsifiers (Christian et al., 2014).

Table 2 provides recent research that developed and applied analytical procedures using spectroscopy techniques in the analysis of various classes of food additives in a range of feedstocks and/or foodstuffs.

3.2. Chromatographic techniques

Chromatographic techniques are a set of analytical techniques employed to separate, identify and quantify inorganic and organic compounds, based on the partitioning or distribution of a sample between a mobile and a stationary phase. The separation occurs due to a series of equilibria between the species of interest and the mobile (gas, or liquid or supercritical fluid) and stationary phase (solid or liquid adsorbed onto a solid support).

Chromatographic techniques are classified according to the physicochemical principles involved in the separation. In adsorption chromatography, the stationary phase is a solid on which the sample components are adsorbed, whereas, in partition chromatography, the stationary phase is a liquid supported on a solid. Ion exchange chromatography employs an ion exchange support as the stationary phase. Exclusion chromatography separates the solvated molecules by their ability to penetrate porous pockets and passages in the stationary phase, associated with their size. These separation mechanisms operate in the two principal types of chromatography used in food additive analysis, gas chromatography (GC) and liquid chromatography (LC) (Jonsson, 1987).

GC is a versatile technique that separates and identifies complex mixtures of volatile compounds and thermally stable organic compounds, using an inert gas as the mobile phase and either an immobilised liquid or a solid packed in a closed tube, as the stationary phase (Nielsen, 2014). The GC instrumentation consists of an inert gas supply, pressure and flow control regulators, injection port of the samples, column, detector, and a data recording and processing system.

Preliminarily, the sample is converted to the vapour state and injected into a column with a controlled temperature gradient to separate the molecules according to several properties, including boiling point, molecular size and polarity. The sample emerges from the column at a constant flow rate and arrives at the detector where the specific response is dependent upon the analyte.

A wide variety of detectors, such as thermal conductivity, flame ionisation, electron capture, flame photometric, photoionisation, electrolytic conductivity and mass spectrometry (MS) are commercially available. The appropriate choice will depend on the nature of the sample to be analysed, and their use can provide either sensitivity or selectivity in the analysis. The detector signal or chromatographic peaks are acquired and displayed by a data system as a function of time. The area under the peak is proportional to the concentration, and so the amount of substance can be quantitatively determined by the construction of a calibration curve prepared in the same manner (Wrostad et al., 2005). Recently, a vacuum UV spectrophotometer was developed to use as a GC detector, which measures the absorption of gas-phase chemical species in the range of 120–240 nm, where all chemical compounds present unique absorption spectra, permitting a facile deconvolution of co-eluting food additives (Santos & Schug, 2017).

The use of GC requires that the sample be volatile and stable at the operational temperatures, typically from 50 to 300 °C. Derivatisations steps to convert compounds to volatile or thermally stable compounds can be realised, but derivatisation is not always possible and/or efficient. Besides, GC analysis of food additive from foodstuffs necessitates rigorous preparation steps, which generally involve preparative chromatography, such as solid-phase extraction or liquid-liquid extraction, headspace analysis and distillation. GC instrumentation has an excessive cost in initial acquisition, maintenance and in the utilisation of the equipment. Furthermore, the analyst must have high expertise and technical knowledge of the technique, restricting its use in quality control to small industries.

Despite the advantages of GC, approximately 80% of known compounds are not sufficiently volatile or stable to be separated by GC. Instead, the use of LC, especially HPLC, is highly adequate, where the mobile phase is a liquid, and the stationary phase is a solid, which can be adequately chosen to improve the separation and identification of different chemical classes of organic and inorganic compounds, according to the polarity of the target compounds.

The LC analyses are based on the adequate choice of a mobile phase, composed by organic solvents and/or buffer solutions, which promote a suitable separation of the target compounds based on their differential affinity between a solid stationary phase and a liquid mobile phase. Classical LC operates at near atmospheric pressure by utilising a peristaltic pump or gravity flow to maintain a constant flow of the mobile phase liquid. HPLC originated from classic LC through the use of pumps and specific detectors that promote improvements in the separation, identification and quantification of organic compounds (Wrostad et al., 2005).

The basic HPLC instrumentation is composed of a pump, injector, column, detector and data system. The mobile phase, called the eluent, use highly pure organic solvents and buffer solutions, which are pumped at a constant flux through the column, promoting the separation of the components by differences in the affinities between the mobile and stationary phase. The pumps allow the isocratic elution arrangements (constant proportion of solvents during the separation) or gradient elution (variation in the ratio organic solvents and buffer solutions during the separation) (Christian et al., 2014).

Pumping systems capable of running a gradient containing up to four components are largely employed in quality control laboratories. The injectors are used to place the sample in the flowing mobile phase, for introduction onto the column. The most common are valve-type injectors and autosamplers, which are employed to inject large numbers of samples, such as in food control analysis.

The type of column employed defines the type of chromatography. Normal phase chromatography utilises a polar stationary phase and relatively non-polar-to-intermediate polarity solvents (hexane and tetrahydrofuran) as the mobile phase. Reverse phase chromatography uses polar organic solvents, such as acetonitrile and methanol joint buffer solvents. Ion exchange chromatography uses ion exchange resins that are composed of particles carrying fixed positive or negative charges. In anion exchange, the stationary phase contains many positively-charged groups (typically quaternary ammonium ions). Negatively-charged species are attracted to the resin and travel more slowly than the column than positively-charged species. Similarly, positively-charged species are attracted to cation exchange resin's negatively-charged groups (sulfonate groups are often the side-chains in cation exchange resins). Ion chromatography uses microparticulate ion exchangers, and the identification and quantification are achieved by conductometric detection. In size exclusion chromatography, the molecules are separated based on their size (Christian et al., 2014).

The HPLC columns are composed by high-purity silica particles with diameters less than 2 µm, to create high back pressure and present minor loss of efficiency at high flow rates, permitting rapid separations. The silanol groups present in silica particles provide polar interaction sites, and these groups can be functionalised, modifying the polarity of

Table 2
 Spectroscopy, chromatography and electroanalytical techniques used in food additives analysis.

Classes	Food additives	Detector	Sampler	LD	Ref.
Flavour enhancer	Maltol	FAAS	Tomato soup, dark chocolate, plain biscuits, fruit cake, pudding, milk wafers, lemon and grape apple juice, strawberry, chocolate and banana milk, fruit yogurt and milk powder	1.24 µg L ⁻¹	(Altway, Girban, & Orhan, 2017)
Flour treatment agent	Amidicarbonyamide	MR	Flour	3.2 mg kg ⁻¹	(Che et al., 2017)
Acidity regulator and colour retention agent	Magnesium hydroxide	AAS	Almond gum and water	0.05 µg L ⁻¹	(Shokrollahi, Hemmatidoust, & Zarghampour, 2016)
Colours	Grotenoids	Raman and UV/Vis	Cornstarch	NR	(Lawwitz et al., 2016)
Flavour enhancer	Glutamic acid	IR	Cereals	NR	(X. Zhang, Lu, Luo, & Zhang, 2017)
Sweetener	Acetosulfame potassium	NMR	Chewing gum, red bean paste, candy, jelly, biscuit, ice cream, jam, salad dressing, vegetable pickled in soy bean sauce, sherbet, soft drink and beverages containing <i>Leuconostoc</i>	0.13 g kg ⁻¹	(Ohnuki, Sato, Abe, Sugimoto, & Akiyama, 2015)
Colours	Curcumin	FLU	Supplements and spices	0.1 mg L ⁻¹	(Petrova et al., 2016)
Glazing agent	Mineral oil	FTIR	Oil	NR	(Polinsky, Proser, Vik, Moravcova, & Pihara, 2017)
Sweetener	Aspartame, cyclamate, saccharin	FTR and Raman	Tabletop sweeteners	NR	(Duarte et al., 2017)
Colours	Allura red	FLU	Candies and beverages	0.002 µg mL ⁻¹	(Bakhet & Zhou, 2017)
Colour	Ponceau 4R	FLU	Beverages	15 µg mL ⁻¹	(J. Zhang et al., 2017)
Colour	Tartrazine, Sunset Yellow, Ponceau 4R and Fast Green	DRS	Barberry taste, orange juice	0.2–0.6 mg L ⁻¹	(Tikhomirova, Ramazanova, & Aysari, 2017)
Colour	Sunset yellow	FLU	Soft drinks	79.6 nmol L ⁻¹	(Yuan et al., 2016)
Colour	Riboflavin	CL and FLU	Tablet	0.63 nM	(H. Wang et al., 2017)
Colour	β-carotene	Raman	Oil-in-water emulsions	0.1–0.3 g kg ⁻¹	(Wan Mohamad, Radzow, Augustin, & McHughan, 2017)
Acidity regulator and antioxidant	Ascorbic acid	FLU	Hawthorn and jujube	39 nmol L ⁻¹	(Xu, et al., 2017)
Colour	Curcumin	UV/Vis	Ginger powder, curry powder and ginger	1.31 µg mL ⁻¹	(Lin et al., 2016)
Bleaching agent and flour treatment agent	Benzoyl peroxide	FTR	Wheat flour	NR	(X.X. Guo et al., 2016)
Emulsifier, gelling agent, glazing agent, anti-foaming agent, bulking agent, foaming agent, stabilizer and thickener	Alginate and carrageenan	NMR	Seaweeds	NR	(Voussout et al., 2017)
Emulsifier, stabilizer and thickener	Guar gum	Raman	Arabic, gellan, karaya, xanthan, locust bean, rosin and ghatti gum	NR	(Srivastava, Wolfgang, & Rodrigues, 2016)
Preservative and colour retention agent	Nitrites	CL	Seawater	0.45 nM	(Foreman, Segura-Noguera, & Karl, 2016)
Sweetener	Sodium saccharin	Raman	Soft drinks	0.3 mg L ⁻¹	(Han et al., 2017)
Preservative and colour retention agent	Nitrite	UV/Vis	Food	3 µg L ⁻¹	(Noor, Tan, Heng, Chong, & Tajuddin, 2016)
Thickener, bulking agent, emulsifier, gelling agent and stabilizer	Sodium alginate	FLU, NMR and IR	Seaweed	NR	(Petrak & Belfiore, 2014)
Preservative and colour retention agent	Nitrite	UV/Vis	Vegetables, fruits, grains, legumes, dairy products, meats	0.10 mg/100 g ⁻¹	(Bahadouran et al., 2016)
Stabilizer, carrier, emulsifier and thickener	Dextrin	FTR and NMR	Salvia miltiorrhiza	NR	(T. Guo et al., 2016)
Chromatography					
Classes	Food additives	Column/ detector	Sampler	LD	Ref.
Preservative and colour retention agent	Nitrite	GC-MS	Raw lettuce, spinach, carrot, kale, arugula and endive	0.2 µg g ⁻¹	(Campaella, Onor, & Pagliano, 2017)

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Table 2 (continued)

Classes	Food additives	Detector	Samples	LD	Ref.
Glazing agent	Mineral oil	HPLC-GC-RID	MR	NR	(Blademann, Munnos, & Grob, 2017)
Anticaking agent, humectant, bulking agent, emulsifier, sweetener and sweetener	Mannitol	HPLC-UV/VIS	Fermented rice	52.1 µg mL ⁻¹	(Chiang, Liang, Wang, & Liang, 2017)
Acidity regulator	Lactic acid, fumaric acid and malic acid	GC-MS	Grape wine	0.07 mg mL ⁻¹	(Tang & Duan, 2017)
Flavour enhancer, sweetener, acidity regulator, preservative	Aspartame, cyclamate, saccharine, acesulfame, acetic acid and propionic acid	HPLC-UV/VIS	Jelly, beverage, tea, juice, coffee, wine, vinegar	0.7–5.0 mg L ⁻¹	(Le et al., 2017)
Antioxidant and colours	Tocopherols, carotenoids	HPLC-MS and HPLC-DAD	Canola oil, palm fruit, sunflower and olive oils	–2.00 µg mL ⁻¹	(Phalakar, Prender, Lockett, Howitz, & Doran, 2017)
Preservative	Benzoate	HPLC-UV/VIS	Beverages	0.003–0.004 mg L ⁻¹	(Pecunovića-Ilijevića, Velkovića-Marićevića, & Jankovićevića, 2017)
Preservative and colour	Potassium sorbate, sodium benzoate, carmoisine, allura red, ponceau 4R	HPLC-UV/VIS	Energy drink, pomegranate juice and mandarin juice	0.10–0.19 µg mL ⁻¹	(Aqil, Ding, Zor, & Abun-Dommes, 2016)
Sweetener	Acesulfame, succharine, cyclamate, saccharose, aspartame	HPLC-MS	Natural water	0.002–0.7 µg L ⁻¹	(Sáez, Borral, Fontanals, & Marcé, 2015)
Flour treatment	α-amylase	HPLC-MS	Corn fructus	NR	(Li, Liu et al., 2015)
Anticaking agent	Peroxyanilides	HPLC-UV/VIS	Reworked salt, burnt molten salt, refined salt, processed salt, solar salt and other salt	0.02 mg kg ⁻¹	(Soo Lim et al., 2018)
Sweetener, acidity regulator and preservative	Aspartame, saccharin, citric acid and benzoate	HPLC-CAD-UV/VIS	Drinks, diet supplements and tabletop sweeteners	0.08–2.7 µg mL ⁻¹	(González, Baran, Blazquez, Fijaño, & Steyer, 2014)
Sweetener	Steviol glycosides	HPLC-FLU	Strawberry jam, low-fat milk, soft drink, yogurt and mixture of steviol glycosides	0.05 nmol	(Bartholomew, Strupf, Lanvers, Ceunin, & Ceunin, 2016)
Preservative	Benzoate	HPLC-UV/VIS	Cheese and yogurt	0.326 mg kg ⁻¹	(Zamani Masdeh et al., 2017)
Acidity regulator	Citric acid and malic acid	HPLC-MS	Apricot liqueur	NR	(Alamatin et al., 2017)
Antifoaming agent	Mineral oils	I.C-GC-RID	Biogenic odours	5 mg kg ⁻¹	(Nesola & Schmidt, 2017)
Acidity regulator, anticaking agent, emulsifying salt, firming agent, flour treatment agent, humectant, raising agent, emulsifier and thickener	Phosphate	HPLC-EELS-MS	Grain	25 ppm	(Doong, Clark, Lapley, & Pegg, 2017)
Colour, antioxidant and	Carotenoid and tocopherol	HPLC-UV/VIS and FLU	Pea, lentil, bean and chickpea	NR	(Pudil, Liu, Hernandez, Tao, & Raudkhan, 2017)
Colours	Tartrazine, Sunset Yellow, Azorubine, Amaranth, Ponceau 4R, Erythrosine, Allura Red, Indigo Carmine, Brilliant Blue, Fast Green, Brilliant Black	I.C-MS	Sugar and gummy confectionary, ice-cream, and chocolate sweets	2–20 µg kg ⁻¹	(Martin, Obergson, Mischler, & Muzart, 2016)
Acidity regulator and colour	Malic acid, carotenoids and Citric acid	HPLC and GC-MS	Grapfruit pulp	NR	(Zheng, Zhang, Quan, Zheng, & Xi, 2016)
Colour	Riboflavin	I.C-MS	Infant formula, breakfast cereal, milk and multivitamin	0.7 mg kg ⁻¹	(Lee, Song, Sim, & Kim, 2016)
Acidity regulator, anticaking agent, emulsifying salt, firming agent, flour treatment agent, humectant, raising agent, emulsifier and thickener	Phosphate	CE-UV/VIS	Fish and shrimp muscle	0.23–0.33 mg g ⁻¹	(L. Wang, Li, & Zhang, 2015)
Antioxidant	BHA, BHT and TBHQ	GC-MS	Oil	0.08–0.10 mg g ⁻¹	(Cocbo, Campillo, Vilas, & Hernández-Griñón, 2016)
Antioxidant	Tocopherol	HPLC-UV/VIS	Palm oil	100.28–175.24 µg L ⁻¹	(Xue, Gu, Morris, & Ng, 2016)
Antioxidant	PG and BHA	HPLC-UV/VIS	Foodstuff	0.14–0.12 mg L ⁻¹	(Márquez Vera, Díez-Pascual, Paz, & Andrés, 2017)
Antioxidant	BHA and BHT	GC-MS	Oil	0.0006–0.0012 mg kg ⁻¹	(Feng et al., 2017)

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Table 2 (continued)

Spectroscopy		Food additives		Detector	Sample	LD	Ref.
Classes		Food additives		Detector	Sample	LD	Ref.
Anticaking agent, humectant, bulking agent, stabilizer, sweetener and sweetener	Mannitol	Solid-state fermented rice		HP/LC-UV/VIS		15.6 g mL ⁻¹	(Chiang et al., 2017)
		Sweetener	Sucralose	HP/LC-HS/D	Commercial sucralose	0.8–2.0 µg mL ⁻¹	(Yan et al., 2016)
			Mineral oil	L.C-GC-UV/VIS	Dry pasta, bread, biscuit and plum-cake	0.03 mg kg ⁻¹	(Moret, Scolaro, Bary, Furcuro, & Omtz, 2016)
Electroanalytical							
Classes		Food additives		Working electrode	Sample	LD	Ref.
Acidly regulator, antioxidant preservative and colour retention agent	Ascorbic acid/nitrite	Orange juice		GCE/CHO-oAP or thionine	Orange juice	0.34–0.82 µM	(Barcolome & Fragoso, 2017)
		Preservative and colour retention agent	Water and sausage extract	GCE/Pt/Fe ₃ O ₄ /polyDOPA/RO		0.5 µM	(Zhao, Xia, Liu, Huang, & Ye, 2017)
Anticaking agent, humectant, bulking agent, stabilizer, sweetener and sweetener	Mannitol		Sugarcane vinasse		AuNP/RO-GCE		7.7 × 10 ⁻¹⁰ mol L ⁻¹
		Flour treatment agent, preservative, bleaching agent and antioxidant	Sulfite	Wine		Screen-printed carbon	
Acidly regulator	Malic acid		Wine		Screen-printed carbon		1.89 µM
		Preservative	Sulphur dioxide	Wine		Screen-printed gold nanoparticles mixed with silver	NR
Colour and preservative and colour retention agent	Amaranth and nitrite		Orange juice, apple juice and sausage		CPE-CuO/SWCMTs		0.001–0.5 µM
		Flavor enhancer	L-Glutamate	NR		CCEMG	
Flavor enhancer	Monosodium glutamate		Unspiced beef		MB-screen-printed carbon		3 µM
		Acidly regulator, anticaking agent, emulsifying salt, firming agent, flour treatment agent, humectant, raising agent, stabilizer and thickener	Phosphate	Water		Screen-printed	
Acidly regulator, anticaking agent, emulsifying salt, firming agent, flour treatment agent, humectant, raising agent, stabilizer and thickener	Phosphate			Seawater		Au electrode	
		Antioxidant	TBHQ and BHA	Oil and margarine, mayonnaise		GCE-MIP/MWCNT	
Colour	Sweet yellow			Mirinda drink and minute milk		GCE/GO and MGO	
		Colour	Ponceau 4R	Soft drink		e-MnO ₂ microspheres/CS/GCE	
Colour	Sweet yellow and tartrazine		Juice and rehydrant		Au-P4RGO/GCE		1.5 × 10 ⁻⁹ mol L ⁻¹
		Colour	Sweet yellow and tartrazine	Orange juice, orange soda and jelly		GCE/AuNBs and ERGO	
Sweetener	Aspartame			Refrigerant and sugar		GCE/ZrONPs	
		Colour	Allura red	Strawberry juice		GCE/PDDA-Gr-Ni	
Antioxidant	BHA and PG			Oil, potato chips and cookies		Au-PT nanorods	
		Colour	Indigo carmine	Candy coated chocolate, jelly powder and food coloring		CPE/NBE	
Colour	Tartrazine, sunset yellow and carmalum			Soft drinks		GCE-MWCNTs	
		Acidly regulator and antioxidant	Ascorbic acid	Orange Juice		Gold	

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Table 2 (continued)

Classes	Food additives	Detector	Samples	LD	Ref.
Preservative and colour retention agent	Nitrite	Pt/Fe ₃ O ₄ /polyDOPA/ERGO modified on GCE	Water and sausage extract	0.5 µM	(Zhao et al., 2017)
Flour treatment agent, preservative, bleaching agent and antioxidant	Sulfite	GCE-AuNPs	Wine	0.045 µmol L ⁻¹	(Yu, Feng, Chen, Wang, & Jiu, 2017)
Addity regulator	D- and L-lactase	Biosensor array chip with platinum	Inoculum sludge	0.7–0.9 µmol L ⁻¹	(Pilas, Yazici, Seliner, Kocogun, & Schönberg, 2017)
Flour treatment agent, preservative, bleaching agent and antioxidant	Sulfite	Pellet electrode modify graphic	Tomato ketchup, jam, sugar, dried grapes and wine	1.7 µM	(Devaramani, Adarshakti, & Mallikarjuna, 2017)
Flour treatment agent, preservative, bleaching agent and antioxidant	Sulfite	CPE/Au-Su/Pk-Q	White wine and coconut water	0.88 mg L ⁻¹	(Winiarski, Barros, Magosso, & Jose, 2017)
Addity regulator	L-lactase	PGE/MPs/PTDDA/AuNP/LOx	Yogurt and fermented milk samples	0.47 µM	(Poz et al., 2017)

FAAS = Flame Absorption Atomic Spectroscopy; NIR = Near Infrared; FIU = Fluorescence; AAS = Absorption Atomic Spectroscopy; UV/Vis = Ultraviolet/Visible; IR = Infrared; NMR = Nuclear Magnetic Resonance; FTIR = Fourier Transformed Infrared; DRS = Diffuse Reflectance Spectroscopy; CL = Chemiluminescence; GC = Gas Chromatography; MS = Mass Spectroscopy; HPLC = High Performance Liquid Chromatography; FID = Flame Ionization Detector; CAD = Charged aerosol detection; LC = Liquid Chromatography; EIS = Electrochemical Impedance Spectroscopy; CE = Capillary Electrophoresis; BHA = Butylated hydroxyanisole; BHT = Butylated Hydroxytoluene; TBHQ = Tertiary Butylhydroquinone; PG = Propyl Gallate; EISD = Evaporative Light Scattering Detection; GCE = Glassy Carbon Electrode; CNO-oAP = Small Carbon Nano Onions-Ortho-Aminophenol; ERGO = Reduced Graphene Oxide; SWCNTs = Single-Walled Carbon Nanotubes; MG = Modified Gold; MB = Meldola's Blue; MWCNT = Multi Walled Carbon Nanotubes Covalently Bonded (Molecularly Imprinted Poly); MGO = Magnetic Graphene Oxide; ERGO = Electro-reduced Gold Nanorods Decorated Graphene Oxide.

the stationary phase according to the polarity of the desired compound to be separated. Sometimes, auxiliary columns, called guard columns, with the same chemical constitution of the column are used prior to the analytical column (Christian et al., 2014).

In food analysis by HPLC, several detectors, which convert the flux containing the mobile phase and target compounds to an electric signal proportional to its concentration are commonly used. Among these, the UV/Vis absorption detector measures the absorption of radiation by chromophore-containing compounds. A fluorescence detector measures the emitted light. A refractive index detector measures the change in the refraction index of the mobile phase, due to dissolved analytes. Electrochemical detectors are based either on electrochemical oxidation-reduction of the analyte or changes in conductivity of the eluent. The MS detector separates and detects ions in the gas phase and is the most sensitive and selective detector used in HPLC and GC (Christian et al., 2014). The coupling of HPLC and GC with MS detection permit the simultaneous determination of various food additives in foodstuffs (Logue et al., 2017).

The main advantages of HPLC are efficiency, a great diversity of stationary phases, high sensitivity due to different detector types and easy recovery of the samples with a suitable resolution. However, the excessive costs of the instrumentation, the necessity of a specialised operator and the generation of toxic residues from organic solvents are the main disadvantages of HPLC.

Capillary electrophoresis has been indicated as a versatile and high-performance tool that enables fast and efficient separations, with low consumption of samples, solvents and reagents. This technique relies on the electro-migration of the concerned species through a capillary under an electrical field. Coupling capillary electrophoresis separation with HPLC or MS permits suitable sensitivity and selectivity in food analysis (Le et al., 2017).

Table 2 lists recent studies that developed and applied analytical chromatography techniques in the analysis of different classes of food additives in various feedstocks and/or foodstuffs.

3.3. Electroanalytical techniques

The last two decades have experienced a considerable increase in the popularity of electroanalytical techniques in food quality control, due to the operational simplicity, low cost and minimum preparation samples steps. These techniques measure the electrical properties, such as current, potential, charge, resistance, conductance, impedance and conductivity, to identify and quantify organic compounds, as the electrical properties are proportional to the target compounds. In food analysis, the electroanalytical techniques that use the applications of potential to promote a reaction of electron transfer following a current measurement, called voltammetric techniques, can be used to identify and quantify food additives in complex samples, such as feedstocks and foodstuffs (Wang, 2001).

In voltammetric techniques, the potential is changed to promote an electron transfer reaction, and the resulting current is recorded as a function of the applied potential, producing a voltammogram that can be used in the identification (peak position) and quantification (peak weight) of the target compounds, but only if this compound is electroactive (reducible or oxidisable). Voltammetric techniques are classified according to the way the potential is imposed on the electrode. Differential pulse voltammetry (DPV) and square wave voltammetry (SWV) are typically used for analytical purposes because the responses are based on the superior elimination of the capacitive/background current, promoting a sensitivity comparable to chromatographic techniques (Scholz, 2010).

In DPV, small pulses of fixed amplitude superimposed on a linear potential ramp are applied in the working electrode where the reaction of interest occurs. The current is measured before and after applying the pulse, producing a resulting signal that is plotted versus the potential applied, and consists of the peak current, with a height directly

proportional to the concentration of the target compound and a peak potential that can be used for its identity (Dahmen, 1986).

In SWV, a waveform composed of a symmetrical square wave, superimposed on a base staircase potential, is applied in the working electrode. The measured current presents excellent sensitivity because the peak currents are measured once at the end of the forward peak and once at the end of the reverse peak, producing a net signal larger than either the forward or reverse signals, consequently generating a sensitivity higher than the DPV (Wang, 2001).

The analytical advantages of DPV and SWV include excellent sensitivity with a broad useful linear concentration range for both inorganic and organic species, a large number of useful solvents and electrolytes, a wide range of temperatures, rapid analysis times (seconds), simultaneous determination of several analytes, and the ability to determine kinetic and mechanistic parameters (Mirceski, Komorsky-Lovric, & Lovric, 2007).

DPV or SWV requires the use of an electrochemical cell constituted by two or three electrodes, called the electric conductor, plus an inert electrolytic solution, called the ionic conductor or supporting electrolyte. This inert electrolytic solution is used to decrease the resistance of the solution, minimise the electro-migration effects and to control the ionic strengths of the medium. Inorganic salts, buffer solutions and mineral acids are frequently used as supporting electrolytes, which can be pure and should not be easily reduced or oxidised in the potential range of the analysis.

The instrumentation consists of two inexpensive integrate circuits, one consists of a polarising circuit that applies the potential between the working and reference electrodes, and one is a measuring circuit that indicates the current that is produced between the auxiliary and working electrodes. Consequently, the instrumentation and the analysis present relatively modest costs and a considerable operational facility, which are the main advantages of the electroanalytical techniques (Wang, 2001).

The change in working electrode promotes alterations in the redox reaction, consequently, altering the current values measured, because the target compounds change their charges at the surface of the electrode, by exchanging one or more electrons with the conductor. In this electrochemical reaction, both the reduced and oxidised compounds remain in solution while the conductor is chemically inert and serves only as a conductor of electrons. The adequate choice of the working electrode depends on the redox behaviour of the target compound and the background current over the potential region used in the analysis. The electrical conductivity, surface reproducibility, potential window, mechanical properties, cost, availability and toxicity, are also important considerations in the implementation of this technique (Scholz, 2010).

Mercury, in the forms of the dropping mercury electrode, hanging dropping mercury electrode and mercury film electrode, was the most used material because it extends the negative potential window, shows high reproducibility, is readily renewable and has a smooth surface. However, in the last two decades, it was substituted by other surfaces, due to the limitation of only cathodic potential regions and high toxicity (Scholz, 2010).

Solid amalgam electrodes, produced from the mixture of a metal powder (e.g., silver, copper, platinum and gold) with mercury liquid following the amalgamation process, presents very close properties to the mercury electrode but without the mercury residues (De Souza, Mascaro, & Fatibello-Filho, 2011). These electrodes are a suitable alternative in the development of sensing devices for food analysis applications.

Solid electrodes composed of carbon and noble metals have been used as working electrodes, adding an extended anodic potential window to monitor oxidisable compounds. However, the analytical responses are dependent on the state of the surface electrode, which requires pre-treatment and polishing steps to obtain suitable responses. Carbon-based electrodes, such as graphite powder with liquid or solid binders, carbon fibres, highly-oriented pyrolytic graphite, carbon

nanotubes and boron-doped diamond, have been evaluated as adequate surfaces in electroanalysis. Platinum and gold electrodes present high analytical responses but a limited range of applications, due to background currents associated with oxide formation on their surfaces (Wang, 2001).

Chemically-modified electrodes represent an important expansion in the applications of the electroanalytical techniques. These electrodes present deliberate surface alterations, to improve the analytical performance and/or resolve many electroanalytical problems, such as sensitivity and selectivity. However, the reproducibility associated with these modifications is the main drawback to its utilisation in food control analysis (Sierra-Rosales, Toledo-Neira, & Squella, 2017; Wang, 2001).

In the last year, the use of electrochemical aptasensors, while are DNA or RNA aptamers with adequate secondary structures that function as ligands in different transduction systems, are capable of binding to a target molecule with high affinity and specificity (Amaya-González, de los Santos-Álvarez, Miranda-Ordieres, & Lobo-Castañón, 2013). The success in the development of an aptasensor involves immobilisation of the aptamer on the transducer surface. Advances in nanotechnology have produced aptasensors with adequate stability and surface coverage by the aptamer while maintaining a high binding affinity in solution, permitting their use in food analysis (Vasilescu, Hayat, Gáspár, & Marty, 2018). The utilisation of porous paper as the substrate for DNA or RNA aptamer immobilisation and construction of an aptasensor for food analysis has also been reported (Vasilescu et al., 2018).

Table 2 highlights recent studies that developed and applied analytical procedures using electroanalytical techniques in the analysis of different classes of food additives in various feedstocks and/or foodstuffs. All these works evaluated analytical protocols to minimise the pre-treatment steps and improve the sensitivity and selectivity of the food analysis.

4. Perspectives in food additives analysis

This review has shown the main food additives classes employed in the processing, packing and storage steps of foodstuffs, indicating the principal compounds and their specific applications. The analytical techniques used by the food industries in the identification and quantification of these food additives were also presented, indicating the advantages and disadvantages of each approach, to supply the necessity of rigorous analytical control and, in this way, ensure a suitable quality and safe food.

In addition, the article presented the literature published in the last 10 years (Figs. 2–4) in which spectroscopy, chromatography and electroanalytical techniques were developed and applied to food additives analysis. Each method presents specific characteristics, including sensitivity, selectivity, analysis costs, efficiency and operational facility, which include minimum sample preparation and ease in instrumentation use.

Nonetheless, the improvement in the quality of the analytical methods and a decrease in the operational costs still need to be considered for direct applications in the quality control by the food industries. In general, in food industries, the chemical composition of the samples is known, and so selectivity is not always the fundamental factor in the choice of the analytical technique. Meanwhile, operational costs, facility in the sample preparations and efficiency in the analysis are essential factors in food quality control laboratories.

The spectroscopic techniques require little or no preparations steps of the sample and present operational facility. However, these techniques have poor selectivity, because all food additives present functional chemical groups that absorb or emit light, and, therefore, cannot be correctly identified using spectroscopic techniques. Although, the use of artificial neural networks can improve the selectivity of food analysis.

The chromatographic techniques promote an adequate separation, identification and quantification of the different classes of food

additives. However, their use demands complex pre-treatment of the food samples and high technical skills by the analyst. Besides, their use in the food industries increases the operational cost in the quality control because of the high maintenance cost, related to employment of high-purity standards and reference reagents, and specific columns. Moreover, the use of chromatographic techniques in food analysis produces toxic residues from organic solvents employed in the analysis.

In the LC techniques, the development of columns specific to food additives classes and the search for mobile phases with low toxicity and low cost are fundamental factors to be considered in food analysis. In GC techniques, the derivatization reactions required to convert the food additives to volatile and thermally stable compounds could be improved to expand the use of these techniques in food analysis control.

The electroanalytical techniques employed require the food additive to present electroactivity (reduction and/or oxidation reactions) at the electrode surface, producing current that is used in its quantifications. These techniques exhibit high sensitivity, operational facility, are fast, simple and low cost. Many materials have been developed to improve the selectivity and thereby enhance the use of the electroanalytical techniques in food quality control. According to Fig. 4, the food additives most commonly evaluated by electroanalytical methods are antioxidants, sweeteners and colourants. The improvement in the pre-treatment of the electrode surface and the development of a material with a homogeneous surface, with respect to electrochemical activity, are fundamental to extend the applicability of electroanalytical techniques in food control analysis.

Development of a specific “fingerprint”, an apparatus able to mimic the human olfactory perception, based on electronic nose measure and an appropriate algorithm, could permit the establishment of the regression models between electronic nose signals and food additives.

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