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# Nanotechnology and food: brief overview of the current scenario

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**Abstract**

The rapidly expanding sector of nanotechnologies has applications in every industrial sector. The production of food of animal origin recognizes several possibilities for technological development through the use of nanomaterials, at animal farming, food processing and product storage levels. Direct use of nanomaterials during these production stages, as well as the uptake from the environment, can lead to the presence of such materials in the final product. In this context analytical methods for the detection and characterization of nanomaterials in complex food matrices and toxicological data are strongly needed to assess the risk for consumers.


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## 1. Introduction

Nanotechnologies are considered to hold a great promise for the development of new products in almost all industrial sectors and many applications are currently marketed worldwide. Among different sectors where a potential for application is recognized, ranging from electronics to health care, from textiles to environment, food has a relevant position.

According to the EU Commission (Recommendation 2011/696/EU) "nanomaterial means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm". This conservative definition comprises all material containing nanoparticles, irrespective of whether their presence is voluntary or not. A different evaluation was made two years before by EFSA in the first opinion regarding nanotechnologies (The EFSA Journal (2009) 958, 1-39) where the Authority, transposing the terminology of SCHENIR (http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_012.pdf), was less concerned about the exact dimensions of particles, but more about their origin. The opinion was actually limited to engineered nanomaterial (ENM) defined as "any material that is deliberately created such that it is composed of discrete functional and structural parts, either internally or at the surface, many of which will have one or more dimensions of the order of 100 nm or less".

Accordingly, the present discussion will be limited to ENM to focus on deliberate use of such materials.

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Having stated that nanomaterials should compel with the previous definition, it is important to describe why their use is steadily increasing and why this trend is expected to continue in the following years.

The main classification of nanomaterials is according to their organic or inorganic nature.

The great advantage of materials at this dimensional state is that they show unique functional properties from bulk materials, properties that can be exploited for a wide range of applications. These properties are mainly due to a high surface to mass ratio that results in a higher reactivity for interactions, ion delivery, or contact. However, other physical-chemical characteristics such as shape, composition, charge, and solubility can change their behavior in an unpredictable way.

## 2. Nanotechnology in agriculture and food

Nanotechnology offers new opportunities also for the food and agricultural industries and several applications can be found at different stages of the food production chain [1,2]:

- agrochemicals delivery;
- nanomaterials for detection of animal and plant pathogens;
- Food and Feed: food additives as color and flavor enhancers, food supplements (e.g. to increase iron or other trace element bio-availability), novel food structure (e.g. nanoemulsion to reduce fat content), nanoparticles for selective binding and removal of contaminants and pathogens from food;
- Food contact materials: nanoparticles with antimicrobial or antioxidant characteristics to boost preservation of foodstuffs, nanoparticles to detect chemicals or foodborne pathogens, biodegradable nanosensors for temperature and moisture monitoring, nanoclays and nanofilms as barrier materials;
- Food supplements: nanoparticle suspensions as antimicrobials, nanoencapsulation for target delivery of nutraceuticals.

This list of applications derives from the recently published "Inventory of nanotechnology applications in the agricultural, feed and food sector" (EFSA Supporting publication (2014): EN-621) aimed at defining the current state of art and the future developments of nanotechnology exploitation in food and agriculture. In particular, it has emerged that 276 nanomaterials (NMs) are currently available on the market; nano-encapsulated, silver and titanium dioxide have the highest number of records in the Nano Inventory and food additives and food contact materials are the most frequent applications. As far as future developments are concerned, it seems that a potential shift from inorganic materials like silver to organic materials like nano-encapsulates and nanocomposites might occur, suggesting that applications in novel foods, feed additives, biocides and pesticides have been so far only at a R&D stage. In this context, there are several applications that could be of interest for products of animal origin, during farming practices, during processing of meat products and during storage and marketing. The use of nanomaterials in the animal production system is described in Fig. 1.

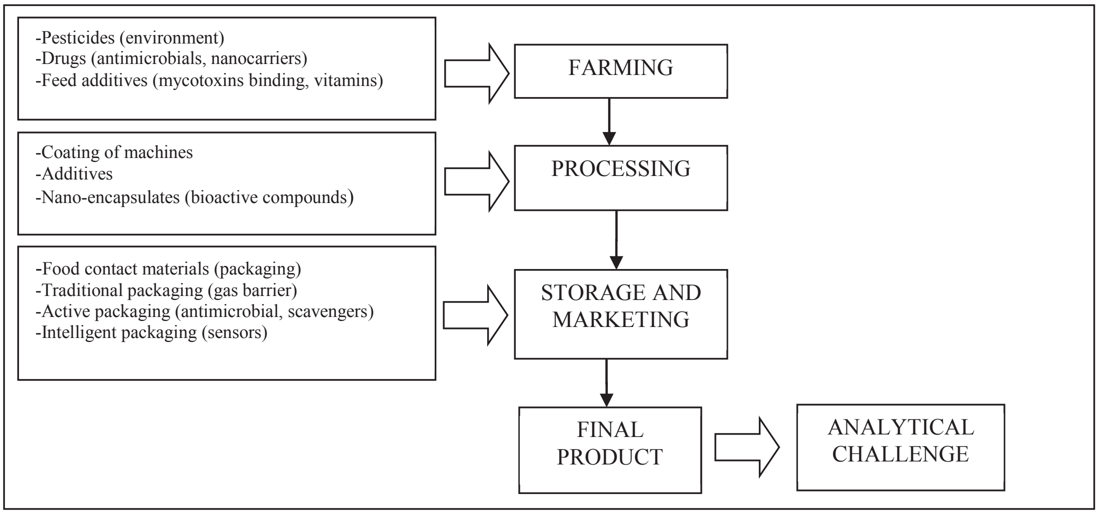


Fig. 1. Example of potential/existing applications in the animal production sector

However, if the benefits of nanomaterials drive their commercial applications and open new scenarios, some concerns arise from the food safety point of view. In this context, the key question is whether nanomaterials are still present in the final products as a consequence of direct use during the production system, uptake from environment or migration from food contact materials. These data, in addition to toxicological information are essential to understand potential risks. For this, research on toxicological properties and the development of analytical methods able to detect and characterize nanomaterials, especially in complex matrices (like food products), are needed.

Despite the increasing use of NMs in food and agriculture, there are limited data about their safety and potential impact on consumers' health. In particular, there are concerns about the fact that nanoparticles (NPs) might cross biological barriers and, due to the increase surface-to-mass ratio and surface reactivity, might have new potential toxicological properties [3,4].

Many NPs, in fact, have distinctly different physicochemical properties, behavior and interactions, compared to their conventional form, which make measuring their potential toxic effects more problematic. As a consequence, it is almost impossible to predict the effects and impacts of NPs by extrapolating the existing knowledge on risks for larger sized particles having the same chemical composition [5].

Unlike the bulk counterpart, NPs are rarely stable and can aggregate according to their different chemical properties (e.g. density, size, shape, surface chemistry) and to the surrounding environment, changing their characteristics over time during an exposure. Consequently, there is the need to understand how NPs and biological parameters can affect in vivo and in vitro toxicity profile.

In addition to this, the lack of standardized or validated methods established for nanotoxicity testing has led to the publication of confusing and often inconsistent data, and is hindering the development of NPs risk assessment strategies.

All these aspects have emerged in the EFSA opinion "The Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety" published in 2009 and are still a current issue.

The lack of exhaustive and complete toxicological data is also due to the actual difficulty to characterize, detect and measure nanoparticles alone and in complex matrices like food/feed and biological samples[6,7] . In fact, beside chemical composition and concentration, size and shape also play an important role on NP behavior. As a consequence, the combination of different analytical techniques is required for a complete characterization:

- size: e.g. Electron microscopy (TEM, SEM), Dynamic Light Scattering (DLS), Centrifugal Liquid Sedimentation, single particle Inductive Couple Plasma Mass Spectrometry (sp ICP/MS), Field Flow Fractionation (FFF), hyphenate techniques such as FFF-ICP/MS;
- Shape: e.g. electron microscopy (TEM, SEM);
- Chemical composition: e.g. Atomic Absorption Spectroscopy (AAS), Inductive Couple Plasma Mass Spectrometry (ICP-MS).

Taking into account that the environment can also affect NP properties, the approach is even more complicated with complex matrices where also sample preparation becomes a crucial step. Complex matrices usually contain different type of nanoparticles that can interfere with the analytical detection. At the same time, sample clean up and preparation might lead to artefacts (e.g. aggregates among particles, aggregate among particles and food proteins or lipids, particle dissolution) and therefore modify the original state of the sample.

All these aspects and the lack of reference materials for a large number of food/particle combinations make the development and validation of analytical methods to detect NPs in food and feed still a challenging and ongoing issue.

## 3. Legislation

The legislation applicable to nanomaterials is complex as well, as described in the following brief overview.

As described in the introduction, the first legal definition of nanomaterials was provided in 2011 in the EU in the form of a non binding legal document. After that, the definition of "engineered nanomaterials" has been included in the Reg. 1169/2011 on the provision of food information to consumer, where the labelling of food products containing nanomaterials is mandatory.

More detailed rules are laid down in other regulations whose application depends on the intended use of the nanomaterials. If nanomaterials are used as primary ingredients (e.g. nanoemulsions), they fall within the scope of "Novel Food" Regulation (258/97) as "foods and food ingredients with a new or intentionally modified primary molecular structure" and they are subjected to a risk assessment procedure before market approval. If they are used as food additives, a different procedure is applied (Reg 1333/2008) and they are expected to be inserted in the EU register before use. In this sector, the definition of nanomaterials appears controversial, since some approved additives, such as Silica (E551), can contain primary particles satisfying the requirements of nanomaterial definition. The main questions in similar cases are whether already approved products discovered to be nanomaterials should be re-evaluated or not, and whether the presence of nanoparticles due to production technology and not to producer willingness should be exempted from further evaluations.

Also, in the case of food contact materials, an approval procedure is required before the inclusion in the EU catalogue. Currently there are few materials approved, such as Titanium Nitride nanoparticles used in plastic materials to prevent carbon dioxide leakage from carbonated drinks, that are recognized to generate no concern since migration has not been demonstrated (Scientific Opinion on the safety evaluation of the substance, titanium nitride, nanoparticles, for use in food contact materials, EFSA Journal 2012;10(3):2641 .

As far as products to be used in the agri sector are concerned, the environmental impact should be evaluated together with the potential for human exposure.

## 4. Conclusion

The development of new products and applications involving nanotechnologies holds great promise in different industrial sectors, food not excluded. Several possibilities exist to exploit the benefits of nanotechnologies during different phases of the food chain with the aim to enhance animal nutrition and health, promote the formulation of new food products and improve the microbiological quality of food during production and processing. Despite these promises, however, nanotechnologies should be carefully applied because toxicological data on several nanomaterials already in use are lacking and because the development of analytical methods able to guarantee consumer protection is still ongoing and need to face several challenges before any routine application in food control could be imagined.

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