The role of colourants in the fertilizer industry

Nowadays, fertilizers can be produced in many different colours. But what is the significance of colour and its role in improving fertilizer product quality? In this article, **Jervis Bao** (Jiabin Bao), R&D director, Arkema China, explores some common questions about colourants and their use in the fertilizer industry.

PHOTO: ARKEMA-ARRMAZ

The origin and importance of colour

When the industrial production of fertilizers first began, their natural colour was largely a reflection of their original constituents and the manufacturing process. In single superphosphate (SSP) and calcium superphosphate manufacture, for example, grey-to-dark colour phosphate rock is reacted with sulphuric acid or phosphoric acid to generate large concentrations of light-coloured calcium sulphate and calcium phosphate. Unsurprisingly, this colour combination results in grey fertilizer granules.

The light grey or green colour of diammonium phosphate (DAP) from Idaho, meanwhile, primarily comes from the phosphoric acid that is reacted with ammonia during its manufacture. Urea and carbonyl diamide, in contrast, are white in colour due to the absence of impurities in their ammonia and carbon dioxide starting materials.

During the first half of the 20th century, it became possible to manufacture many more types of fertilizer in greater quantities due to rapid advances in production technology – a transformation that propelled the fertilizer sector from its relatively modest origins into a fully-fledged standalone industry.

By the end of the last century, the fertilizer industry had developed a sophisticated range of complex speciality fertilizers suitable for many different agricultural applications globally. At the same time, the use of colourants emerged as an increasingly important way to brand or differentiate individual fertilizer types. DAP fertilizers from Florida and North Carolina, for example, became very popular and widely recognised as 'magic granules' in North American agriculture due to their signature natural dark brown colour.

Today, colour is an important differentiator for fertilizers. Producers use colourants:

- To differentiate their fertilizers from those of other producers
- To meet regional and customer colour preferences
- As functional additives or coatings to reduce dust formation and prevent caking.

What are colourants and why are they used?

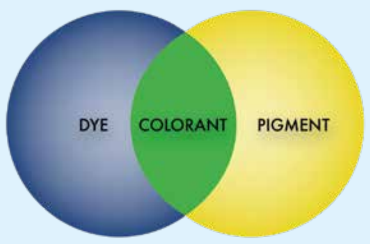
A colourant is an added or applied substance that changes the outward or surface colour of a material[1]. Colourants are used for many processes, notably printing and painting, and for creating a distinct hue in many types of materials including foods and plastics[2]. They can be divided into two main types:

- Natural colourants, e.g. hematoxylin and humate
- Synthetic colourants, e.g. lemon yellow.

Colourants can be a dye or a pigment or a combination of both (Figure 1). A dye is a material that is dissolved in a solvent such as water or oil to colour other substances, whereas pigments are tiny solid particles dispersed in a substance to create colour without using a solvent[3].

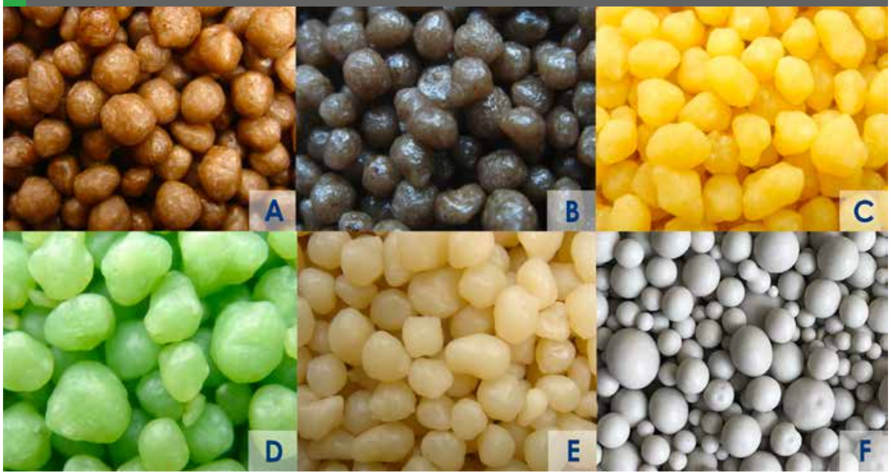
As the fertilizer industry has developed, colourants no longer simply function as colouring agents. Instead, they have evolved into additives with a comprehensive range of qualities that can:

Fig. 1: **Dyes and pigments vs colourants**



Source: Arkema and ArrMaz Products Inc.

Fig. 2: **Differently coloured fertilizer granules, including coloured DAP (A-D), base colour DAP (E) and base colour NPK (F)**



SOURCE: ARKEMA-ARRMAZ

- Provide a uniform appearance
- Quickly and clearly differentiate different fertilizer types
- Offer improved quality
- Highlight product value or indicate nutrient type.

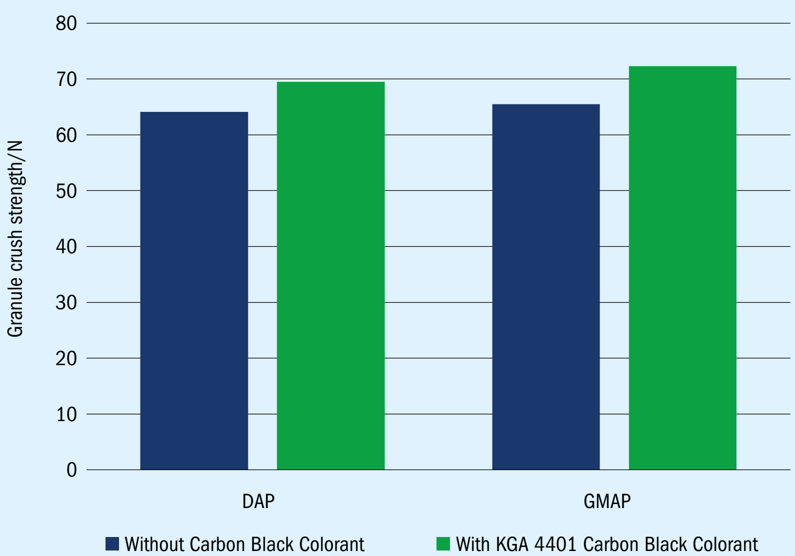
Uniform appearance

As already indicated, although the colour of fertilizers primarily depends on raw material composition, many other factors can affect colour – including process control, impurities, moisture content etc. Colourants are used by the fertilizer industry to overcome raw material fluctuations and ensure that manufacturing generates products with a consistent colour. Producers also create special colours to verify the authenticity of their products by functioning as anti-counterfeiting marks.

Differentiation

Most fertilizer manufacturers use distinctive and individual colours to classify different nutrient grades. This colour coding helps farmers to identify and apply the correct fertilizer substrates to crops at each growth stage (Figure 2). During the bulk blending of fertilizers, the different colours of individual fertilizer components make it easier to evaluate the overall homogeneity of the bulk fertilizer blend. In fertilizer production processes, colourants are also added as a tracer alongside micronutrients. In this way, the colourant is able to ensure homogeneity by visually showing the coverage and distribution of the micronutrient on granules or powders.

Fig. 3: **Impact of carbon black colourant on granule crush strength**



Source: Arkema and ArrMaz Products Inc.

Improved quality

Some inorganic chemical colourants also aid the fertilizer granulation process. For example, carbon dust (from coal slag) is added to phosphoric acid during the ammonium phosphate granulation process and reacts with ammonium to create small particles. By acting as seed crystals, these improve crystallisation and create higher strength fertilizer granules.

Water-insoluble liquid colourants are also used as coating agents. As well as imparting colour, these improve product quality by providing good anti-dusting and anti-caking properties. For example, coating with a carbon black colourant, by increasing granule strength, reduces dust formation and prevents caking (Figure 3).

An indicator of nutrient type or value

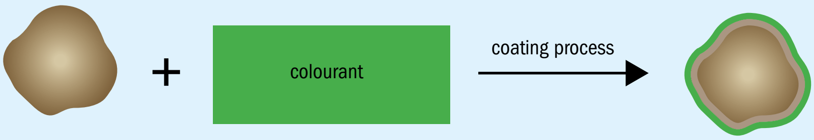
Some nutrients and biostimulants, and the value they provide, can be identified solely from their natural colour. Fulvic acid, for example, is a natural yellow-brown colourant that boosts crop growth as well providing colour. The same is true of red iron oxide. Sulphur-coated urea, which is valued as a slow-release fertilizer, is also identifiable from its yellow colour.

Fig. 4: **Three physical states of fertilizer**

Solid granular fertilizer | Solid powder fertilizer | Liquid fertilizer

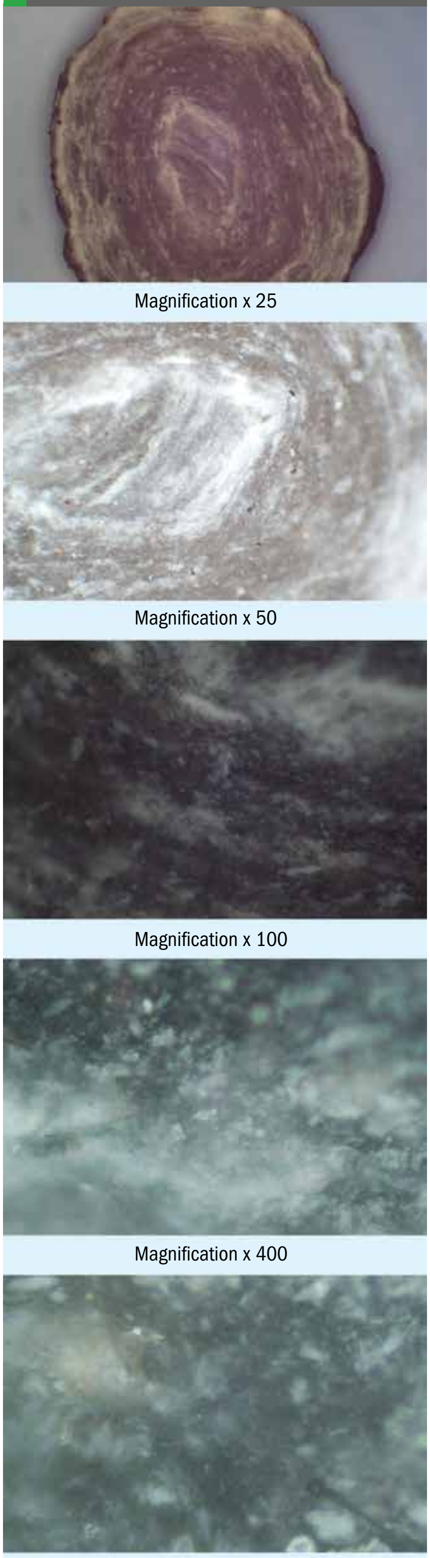
Source: Arkema and ArrMaz Products Inc.

Fig. 5: **A coating process is used to cover the fertilizer granule surface with the colourant**



Source: Arkema and ArrMaz Products Inc.

Fig. 6: **Cross-section of a single fertilizer granule at different magnifications showing colourant performance and distribution**



Magnification x 25

Magnification x 50

Magnification x 100

Magnification x 400

Magnification x 600

Source: Arkema-ArrMaz

Applying colourants

Fertilizers are commonly offered to the market as solid granules and powders as well as in liquid form (Figure 4).

Some colourants can be directly or indirectly applied to the surface of solid fertilizers. Talcum and iron oxide powders, for example, are used to impart a white and red colour, respectively. However, most colourants are formulated as oily liquid solutions. These are designed to maximise adhesion and completely cover the original appearance during coating (Figure 5). In contrast, aqueous solutions of colourants are hardly ever used because of the potential for fertilizer caking.

Other colourants are incorporated within the fertilizer during the production process. Water-soluble dyes are usually used for this purpose, as high concentrations of water are present for much of the fertilizer production process, eventually requiring a drying stage[4]. However, pigments can also be mixed with fertilizer raw materials (e.g. phosphoric acid, liquid urea) or fertilizer slurries (e.g. ammonium nitrate) to achieve good colouration. For a homogeneous colour, these pigments must dissolve easily in water or disperse very well in slurries, so ending up within the fertilizer's crystal lattice[5] (Figure 6).

Colourants are typically added to the fertilizer at 0.05-0.30 weight percent, the exact amount depending on the colour requirements of each market. Colourant performance – particularly the homogeneity of distribution with fertilizer granules (Figure 6) – is also the deciding factor for dosing levels.

Formulating colour

The colour of an object or substance can be determined using CIELAB 'colour space', an international standard developed by the Commission International del'Eclairage in 1976. Using CIELAB, suppliers such as Arkema-ArrMaz are able to formulate colourants to meet the colour needs of both fertilizer producers and the market.

The CIELAB colour space is composed of three values, L, A and B, as follows (Figure 7, Table 1):

- **'L' value for brightness:** ranges from 0 to 100 for pure black to pure white.
- **'A' value for green to red:** ranges from -128 to +127 for dark green (low brightness) to grey (medium brightness) to bright pink (high brightness).
- **'B' value for blue to yellow:** ranges from -128 to +127 for bright blue (low brightness) to grey (medium brightness) to yellow (high brightness).

Colours can be mixed according to these values to produce the desired result[6].

Colourant safety

Fertilizer safety is a priority for the whole industry. In China, for example, the government published a new fertilizer safety standard in 2019 (GB 38400-2019 Limitation Requirements of Toxic and Harmful Substance in Fertilizers) and implemented this the following year. The standard strictly controls heavy metal and phthalate ester content (Table 2). The levels of hazardous chemicals in fertilizers are also regulated (to some extent) in most countries globally. Consequently, many of today's fertilizer colourants – such as those provided by Arkema-ArrMaz – are developed to meet or exceed stringent safety and environmental standards.

Summary

In the early stages of the fertilizer industry, fertilizer colour was largely dependent on the raw materials used to make fertilizers. Subsequently, as additional and more complex varieties of fertilizer were developed, colourants were used to differentiate between these, as well as to achieve a homogeneous visual appearance. Today, fertilizer colourants are able to provide the following benefits:

- Uniform visual appearance.
- Quick and efficient differentiation between different types of fertilizer, nutrient grades and micronutrients.
- Improved fertilizer quality with reduced dust formation and caking.
- Easy identification of nutrient type or product value.

Using CIELAB colour space, suppliers like Arkema can formulate a colourant to meet customer needs and market preferences and comply with stringent regulatory standards. ■

References

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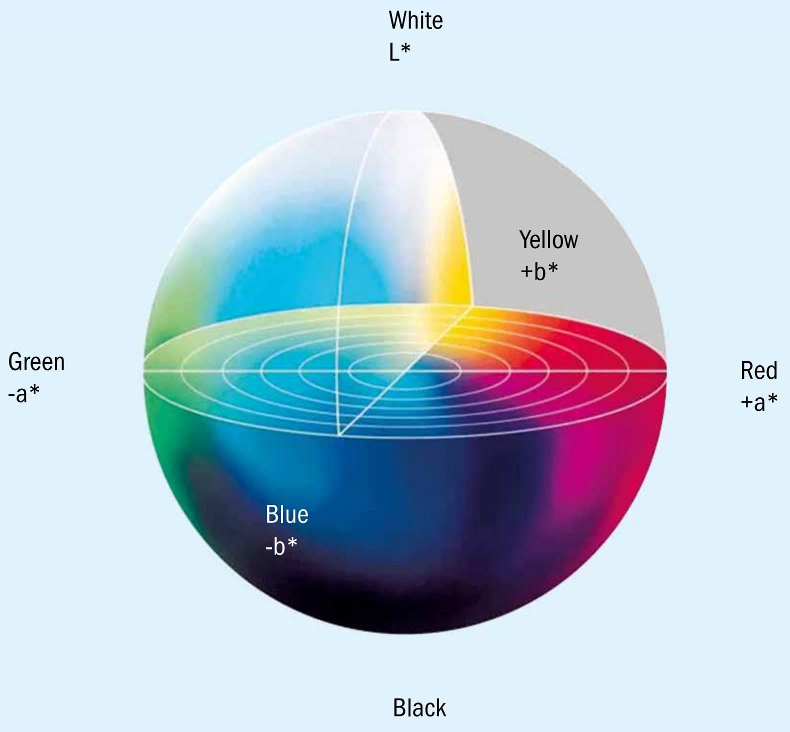
Fig. 7: **LAB colour panel**



Source: Linshang Technology

Table 1: **CIELAB values for popular granular fertilizers**

Fertilizer	Colour	L value	A value	B value
Urea	White	92.0 to 96.0	-1.0 to +1.0	0.0 to +2.0
DAP	Dark brown	25.0 to 29.0	+3.0 to +5.0	+9.0 to +13.0
DAP	Yellow	56.0 to 62.0	+7.0 to +8.0	+38.0 to +46.0
DAP	Green	48.0 to 56.0	-14.0 to -10.0	+22.0 to +28.0
NPK	Black	12.0 to 15.0	-0.5 to +0.5	0.0 to +1.0

Source: Arkema and ArrMaz Products Inc.

Table 2: **Limits specified by China's GB 38400-2019 fertilizer safety standard**

No.	Items	Limits	
		Inorganic fertilizer	Other fertilizer
1	Total Cd	≤ 10 mg/kg	≤ 3 mg/kg
2	Total Hg	≤ 5 mg/kg	≤ 2 mg/kg
3	Total Se	≤ 50 mg/kg	≤ 15 mg/kg
4	Total Pb	≤ 200 mg/kg	≤ 50 mg/kg
5	Total Cr	≤ 500 mg/kg	≤ 150 mg/kg
6	Total Tl	≤ 2.5 mg/kg	≤ 2.5 mg/kg
7	Biuret	≤ 1.5%	≤ 1.5%

Source: Arkema and ArrMaz Products Inc.