2-Phenylethyl Alcohol: An Aroma Profile

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Phenylethyl alcohol is a higher aromatic alcohol characterized by a delicate fragrance of rose petals starting at 20 ppm. Above 40 ppm, this aroma becomes an undesirable in foods. Generally, the higher alcohols are quantitatively the largest group of volatile compounds and their presence is essential to the overall flavor quality. These alcohols also can play indirect roles as precursors in the preparation of other flavorants. For example, alcohols can be oxidized to aldehydes or used for the production of esters.

Phenylethyl alcohol followed ethyl alcohol as the main commercial alcohol.[1] It is the most used fragrance in the perfume and cosmetic industries. It is found in the composition of numerous perfumes in various proportions, from 5–20%. With regard to its world consumption, several studies have come up with the figure of 7,200 metric tons per year; however, in foodstuffs (1–3 ppm in soft drinks, candy and cookies), the consumption is estimated at only 10 metric tons per year.

The properties of such an aroma are described in Table I. Freshly prepared phenylethyl alcohol, free from impurities, possesses an aromatic appeal described as a rose-like aroma. The material available on the market is produced mainly by chemical processes. It is added to modify certain flavor compositions, especially fruit formulas, where it contributes organoleptically.

Table I. Properties of phenylethyl alcohol

	Properties
Formula	$C_8H_{10}O$
Aspect	colorless liquid
Molecular weight	122.17 g/mol
Boiling point	220-222°C
Density	1.02 at 25°C
Solubility in water	1-60 (19 g/l)
Organoleptic characteristic	rose-like aroma
CAS No. 60-12-8, FEMA-GRAS No. 2858	

Vegetal Sources

Phenylethyl alcohol is found in a fair number of natural products used worldwide. It has been reported as a minor constituent (from 1-5%) in the essential oils (from 1–5%) of the following vegetal substrates: narcissus, hyacinth, *Bourbon geranium*, *Alep* pine, rose (*Rosa centifolia*) and jasmine. A rose absolute, obtained by chemical treatment of rose floral buds, can contain up to 60% of phenylethyl alcohol.[2]

Because of their rarity, the essential oils command a high price. There is little information concerning the price of these oils; however, some market estimates indicate that such products could be sold for 300-400 times more than the corresponding chemical aroma. An example is shown in Table II.

In spite of the high cost of such an aroma, the demand for natural phenylethyl alcohol from vegetal sources continues to outstrip the supply. Accordingly, the flavor industry is turning to the production of aromas obtained by biotechnological processes.

Table II. Price of the rose-like aroma according to its origin (in French francs per Kg)

Origin of the rose-like aroma	Company	Price
Essential oils of rose	-	20,000
Chemical 2-phenylethyl alcohol	Rhône-Poulenc	43
Chemical 2-phenylethyl alcohol extra	Givaudan-Roure	68

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Microbial Sources

Many higher alcohols are the major metabolites of microorganism fermentation. The predominant alcohols are ethanol, fusel oil alcohols (propanol, isobutanol, amyl and isoamyl alcohol) and phenylethyl alcohol. We'll discuss Ehrlich pathways and other pathways of amino acid degradation as sources of 2-phenylethyl alcohol.

Ehrlich Pathways

These alcohols are formed by reduction of α-keto acids, which can be derived from either biosynthesis or the degradation of amino acids. When amino acids are added to the fermentation, they undergo transamination followed by decarboxylation of the resulting keto acid to the corresponding aldehyde. The aldehyde is then reduced by alcohol dehydrogenase to a higher alcohol having one less carbon atom than the substrate amino acid. This corresponds to the Ehrlich pathway.[3] One can manipulate the fermentation conditions to favor higher metabolic activity but limit cell growth, resulting in increased production of the higher alcohol.[1]

Some bacteria, such as *Microbacterium* sp., cultivated on a liquid medium (*Soya trypcase*), produce only a few milligrams per liter of phenylethyl alcohol. It contributes to the floral fragrance of the cultures.[4] *Brevibacterium linens* also synthesizes phenylethyl alcohol during the phenylalanin assimilation by the Ehrlich pathway; however, this strain is not able to accumulate this compound because it is degraded in turn. Moreover, certain yeasts, notably *Saccharomyces cerevisiae*, produce phenylethyl alcohol that is important in the flavor of beer, whiskey and sake.

Hanssen et al[5] showed that *Kluyveromyces lactis* synthesizes 70 volatile compounds, the main molecules being ethylacetate, isobutyl alcohol, isoamyl alcohol, 2-phenylethyl acetate and 2-phenylethyl alcohol, whose concentration reaches 240 mg/l after 17 days of incubation. The works of Jiang,[6] carried out with *Kluyveromyces lactis* CBS 5670, confirm that this strain mainly produces isoamyl alcohol and 2-phenylethyl alcohol; after five days in Erlenmeyer flasks incubated at 30°C, the concentrations reach 73 and 72 mg/l, respectively.

Most studies concerning 2-phenylethyl alcohol production by yeast reveal that concentrations don't exceed 100 mg/l. However, the results of Albertazzi et al[7] show that yeasts such as *Saccharomyces cerevisiae* and *Hansenula anomala* are able to accumulate up to 1.57 and 1.73 g/l, respectively, from 2 g/l of phenylalanin. The strains *Pichia pastoris* and *Kloeckera saturnus* continue the bioconversion up to the corresponding ester, 2-phenylethyl acetate. The study of Fabre et al[8] also reports that *Kluyveromyces marxianus* treated by UV could produce up to 3.4 g/l of phenylethyl alcohol by fed-batch process.

Finally, this compound is observed as a metabolite of such fungi as *Polyporus*, *Phellinus* and *Penicillium*.[1] For example, a study concerning *Polyporus benzoinum* shows that this strain produces 360 mg/l of phenylethyl alcohol.[9]

Other Pathways of Amino Acid Degradation

Several studies reveal that an amino acid could be degraded in other ways, depending on the selected strain. After decarboxylation, an amino acid such as phenylalanin is transformed into phenethylamin, an intermediate that can lead to phenylethyl alcohol accumulation in *Saccharomyces rouxii, Ceratocystis fimbriata, Torulopsis versalitis* and *Candida albicans*. When the phenylalanin undergoes an initial deamination, the metabolism can be led in two directions: the cinnamate pathway or the phenylpyruvate pathway.

Cinnamate pathway: The cinnamate pathway is observed in *Sporobolomyces roseus, Rhodotorula* sp., *Aspergillus niger* and *Polyporus hispidus*.[10]

Phenylpyruvate pathway: The phenylpyruvate pathway occurs by oxidative deamination of the amino acid. In the case of phenylalanin, the substrate is converted into phenylacetaldehyde and phenylacetate. *Proteus vulgaris* is able to transform 20 g/l of phenylalanin into phenylpyruvate.[11] However, it is possible to observe in *Polyporus hispidus* the degradation of phenylalanin along both pathways simultaneously.

Conclusion

The growing market for natural aromatic flavorants has stimulated work on the elucidation of the pathways of aromatic biosynthesis and on specific whole cell and enzymatic routes. A better understanding of microbial routes to and from phenylethyl alcohol will certainly facilitate the development of a fermentation process for production of rose-like aroma.

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