Alcoholic beverages contain, apart from ethanol low concentrations of higher aliphatic alcohols, esters, aldehydes and other carbonyl compounds. Gas chromatographically RAPP et al (16) have found for example up to 600 such substances in wine extracts after enrichment. The origin and significance of these congeners is still rather obscure. It is certain, that they are extracted partially unchanged in form from the raw material, however, they are also partially a result of the fermentation process. Thus it has occasionally been supposed, that the congener spectrum of an alcoholic beverage can yield information about its origin and manufacturing process. Enlightening analyses of alcoholic beverages actually showed differing congener patterns between the various classes of alcoholic beverages (10,12,13).

We ourselves have formed a general view of approximately a thousand analyses of alcoholic beverages (3,4,6). According to our experiences, it is for example possible to discriminate american whiskies and french cognacs by means of their particularly high concentrations of 2- and 3-methylbutanol-1. One can clearly distinguish them from other brandies and whiskies. Stone-fruit brandies and, to a lesser extent, the other fruit brandies contain butanol-2, often in considerable quantities, and also a particularly large amount of methanol. Rums and
liqueurs exhibit considerably lower contents of congeners; instead one can trace to a certain extent high concentrations of different esters, particularly in sugar-cane brandies. Clear spirits, i.e. corn brandy and vodka (also gin and aqua-vitae), are practically entirely free from congeners. Wine and beer contain fewer congeners; due to the lower ethanol content they can, however, be consumed in greater quantities.

The interest in congeners for forensic medicine lies first and foremost in the following three aspects:

a) It is debated whether they influence the pharmacological effects of the beverages.

b) It is theoretically conceivable that they cause changes in the rate at which ethanol is eliminated.

c) After consumption of different alcoholic beverages one can expect varying congener patterns in the blood and urine. These patterns permit us to draw conclusions about the sort of alcoholic beverage consumed.

In respect to the pharmacological effects, it is generally supposed, that the congeners influence the taste and tolerability of a beverage. During experiments where the subjects consumed the beverages, it was repeatedly observed, that those who consumed whisky containing equal amounts of ethanol developed more serious organic and psychological deficiencies than the consumers of vodka; and these deficiencies were greater than those shown by the consumers of a mixture of pure ethanol and water (8, 15). The symptoms of the resulting hangover are obviously linked to the congeners or their metabolites (7). MA-CHATA and PROKOP (14) expressed the opinion that the earlier investigations had been based on artefacts. They assumed that the congeners had only brought about an improvement in the absorption of ethanol as a result of a hyperemia of the intestinal mucosa. They supposed that this resulted in different increased concentrations of alcohol in the blood in spite of an identical consumption of ethanol. These concentrations could be held re-
sponsible for the differing deficiency symptoms. The opinion, that the congeners lead to a relative increase in the blood-ethanol concentrations was similarly shared by VON WARTBURG et al (19) as well as AUTY and BRANCH (1), but it was differently accounted for. By means of perfused liver slices both groups established a competitive inhibition of ethanol oxidation on the ADH as a result of the higher alcohol. The concentrations of alcohols used were of course much higher than those usually appearing in beverages.

It is thus not surprising, that in 1969 HEDLUND and KIESSLING (11) described their experiment on animals as turning out "unexpectedly and unaccountably" when they demonstrated exactly the reverse reaction and were unable to account for it. As far as we know, experiments on humans have not been carried out. This problem has thus occupied us within the scope of our experiments with congeners. 10 volunteers were given 3.75 ml/kg body weight of a synthetic beverage with 40 % ethanol in orange juice and an additional 1 g/l of a designated specific higher aliphatic alcohol.

It could be seen, that the concentration-time curves level out with the increasing carbon-chain length of the aliphatic alcohols and reach not detectable amounts at varying times. In our opinion one must take into consideration changes in the conditions of absorption.

In our view the main significance of congeners in alcoholic beverages seems to lie within the sector of a possible determination of types of beverages with the help of results from blood and urine analyses. Like MACHATA and PROKOP (14) we had already made the observation that after the consumption of different alcoholic beverages varying concentrations of congeners could be traced in the blood and urine of the consumers (5).

In order to draw conclusions from blood and urine analyses, which might be of use to forensic medicine, it was necessary to gain accurate information about the distri-
bution in the body of the most important congeners and their elimination. It was also necessary to rule out post-hume artefacts, e.g. the regeneration of congeners during storage or their disappearance as a result of autolysis in respect to decomposition processes.

With respect to the changes during storage and decomposition one can say that no significant reduction or regeneration of alcohols occurs, when blood samples are properly stored for 1.5 years at +4°C. Artefacts can appear in blood samples from corpses, especially in the case of drowned persons, and occasionally if the samples are not properly stored. In such cases we have always found a steep increase in the butanol-1 values, which could not result from the consumption of alcoholic beverages, as all drinks only contain very small quantities or mere traces of butanol-1. Butanol-1 concentrations over 0.1 mg/l in blood samples should thus cause us to reject their values for forensic purposes.

When regarding the question of the distribution of alcohol after its absorption, one must take into account its varying lipid solubility. This factor caused MACHATA and PROKOP (14) to consider a depot formation in organs rich in lipoids. While investigating organs from corpses we were personally unable to establish any great discrepancies, which exceeded the water content. Our view is confirmed by the pronouncement by RIETBROCK and ABSHAGEN (17) who state, that the distribution volume of the higher alcohols is set at 90 % up to 98 % and is thus higher than that of ethanol.

Up till now little is known about the metabolisation of the higher aliphatic alcohols. It was mostly assumed that only the straight-chain primary aliphatic alcohols were broken down by means of ADH, and that the duration of this process lay in direct proportion to the length of the carbon chain. Many authors even believe, that a real metabolisation of the higher alcohols only came about after the complete elimination of ethanol. This idea is
contradicted by the results of the in-vitro experiments by WINER (20) and similarly in the synopsis of TREON (18) which showed that the initial rate of ADH oxidation decreases in the order of butanol-1 : 3-methylbutanol-1 : propanol-1 : ethanol. Unlike ethanol, the elimination of the higher alcohols proceeds exponentially, according to observations, made by RIETBROCK and ABSHAGEN (17) in experiments with animals. This also corresponds to our own observations in experiments with human beings. According to our own experiments the absorption-elimination curves of the alcohols resemble each other in principle, including the branch-chain and the secondary ones. After consumption of identical amounts the maximum concentration is reached at its lowest point, when the carbon chain of the alcohol is at its longest. All cases point to exponential curves.

ADH is responsible for the breakdown of the higher alcohols. According to WINER (20) and GREENBERG (11) the resulting aldehydes are rapidly metabolised by the same enzyme, and, most likely, by AlDH. For us it was only ever possible to detect relatively small concentrations of aldehydes and only at later times of experimentation, which under certain conditions would permit us to draw conclusions about the time of consumption. The ketones, i.e. the metabolites of the secondary alcohols, are yet another matter, as they nearly cannot be broken down by both enzymes and further. Acetone (from propanol-2) and ethylmethylketone (from butanol-2) become richer in blood and are eliminated in this form.

According to RIETBROCK and ABSHAGEN (17) the elimination takes place in unchanged form according to the alcohol between 4 and 10 % of the entire amount absorbed, and it is eliminated predominantly in urine, but also in the breath, saliva, sweat, stomach juices and bile. According to our investigations the direct elimination into the urine is no higher than 4 to 12 %, depending on the chain length. The concentration-time course equals in all
cases the blood picture except for the expected shift of the maximum respective alcohol concentration in the urine. From literature on this subject it is known that the aliphatic alcohols can also be eliminated in the form of their sulphates and, more important, in the form of their glucuronides. RIETBROCK and ABSHAGEN (17) put the elimination of propanol-2-glucuronic acid conjugates at around 10 %, DIVINCENZO and HAMILTON (9) put it at 4.4 % for the corresponding butanol-1 conjugate, and BERGGREN (2) likewise. TREON (18) observes that in rabbits 3-methylbutanol -1 is eliminated as glucuronide "in small quantities".

Our trials with medical student volunteers have had quite different implications. The glucuronides reach 40 (!) % in certain cases of alcohol with long chains. This is of advantage for the determination of the type of beverage by urine analysis; for with the help of glucuronidase treatment of urine samples there is a good chance of tracing the alcohol in question even if only a small amount of alcoholic beverages have been consumed. The glucuronides do not concentrate in blood, as known, and are easily eliminated through the urine. Sulphates of aliphatic alcohols also appear in urine and blood, although only in a concentration of 4 to 10 %. Sulphatase treatment of blood samples can thus improve the chances of detection.

What conclusions can be drawn from the results of these experiment?

1. The higher aliphatic alcohols can lead to a change in the development of the blood-ethanol curve after the consumption of alcoholic beverages containing congeners.
2. From the content of congeners in blood and especially in urine samples it is possible to draw conclusions about the sort of beverages consumed.
3. It seems possible to receive information about drinking time from the presence of metabolites depending on their concentration.
References


13. Lemperle, E., Mecke, R.: Gaschromatographische Ana-
lyse der flüchtigen Inhaltsstoffe von Weinen, Mosten und Spirituosen. Z. Anal. Chem. 21, 18-30 (1965)


