Chapter 07

The Value of Gaseous Hydrogen Generated by the Intestinal Microflora of Human

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Abstract

Considering the significant amount of gaseous hydrogen contained in the human intestine, as well as its physical and chemical properties, it can be assumed that it participates in processes that occur in the human body. For example, we can assume the participation of gaseous hydrogen of intestinal origin in digestive and bioenergetics processes, and also in processes that determine the activity of genes and cell proliferation. In addition, one can easily imagine the direct participation of such hydrogen in DNA repair damaged by reactive oxygen species. In any case, the possible effect of gaseous hydrogen of intestinal origin on the human body needs to be discussed.

Keywords

Intestinal Gas; Krebs Cycle; Bioenergetics; Aging; Starch Diseases; ROS; Oxidized DNA; Circadian Rhythms

Introduction

Because of the different composition and activity of the intestinal microflora, the proportion of gaseous hydrogen in the human intestinal gas can vary from 20 to 34% (vol.) [1], which is comparable to the oxygen content in the air [2]. As a result, the internal organs of a person exist in a kind of gas gradient formed on the one hand by an intestinal gas containing hydrogen gas and, on the other hand, air having an equivalent content of gaseous oxygen [2]. Since aqueous hydrogen gas is an electron donor and the aqueous oxygen gas is an electron acceptor [2], an electric field is constantly acting between the intestine and the human skin, which can affect its internal organs. For this reason, it naturally becomes necessary to discuss the possible influence of such an electric field on the processes occurring in the internal organs of man, primarily on the processes occurring in his digestive system.

At the same time, there arises the need to discuss the possible participation of gaseous hydrogen in intracellular processes—this is
due to the high penetrating ability of gaseous hydrogen (Figure 1) [2,3], and also to its chemical properties.

Figure 1: So it looks like a closed PET bottle with hydrogen gas a few weeks after filling it. The changes that have taken place with the bottle show that hydrogen gas can freely penetrate through the plastic [3].

So, let’s first discuss, the possible effect of the described electric field on the human digestive processes. It is known that most nutrients that enter the intestine or are formed in it, have or acquire an anionic nature: fatty and organic acids, amino acids (at pH ~ 8), glucose phosphate [4]. The anionic nature of nutrients can be very important for their transfer into the blood, because of the influence on them of the mentioned electric field that exists between the intestine and the skin. The reason for the occurrence of such a field must be explained further. This electric field arises because the gaseous hydrogen of the intestine and the atmospheric air form an analogue of the air-hydrogen electrochemical cell (Figure 2) [2], whose field is directed from the surface of the skin into the intestine, – it is clear that under the action of such a field the anions will move from the intestine to the outside.
Thus, it can be concluded that the microflora of the human intestine, more precisely – the hydrogen gas that it generates is necessary for the efficient transfer of nutrients from the intestine to the blood. This, in particular, shows that the composition and activity of the microflora of the human intestine can affect not only the digestion of a person, but also his organism as a whole.

Let’s continue to discuss the value of the described electric field for a person. So, considering the principle of its functioning (Figure 2), it can be assumed that the described motion of anionic nutrients depends on the sign of the electrical potential of the air, which can vary along with the atmospheric pressure – it should be more active at a higher atmospheric pressure and less active at a lower atmospheric pressure. The last assumption is based on an experimentally established relationship: air has a negative charge at low atmospheric pressure and a positive charge at high atmospheric pressure [5].

Figure 2: This is the scheme of an air-hydrogen electrochemical cell [2]. Red arrows indicate the movement of electrons from the compartment with an aqueous solution saturated with hydrogen gas, into the compartment with an aqueous solution saturated with air. Anionic nutrients can also travel from the intestine in contact with hydrogen gas to the surface of the skin in contact with air.
In other words, anionic nutrients are more active in the blood in good weather and less active – in bad weather. And since the activity of bioenergetics processes occurring in cells depends unambiguously on the intensity of energy substrates entering into them, it can be expected that the activity of cellular bioenergetics processes will also correlate with weather conditions (apparently, this is the basis of our perception of both good and bad weather).

You can also expect that the activity of nutrients in the blood, and the activity of cellular bioenergetics depend on the time of day: they are more active in the daytime and less active at night. The latter assumption reflects the diurnal variation of the electric charge of the earth's surface, which in daytime has a more positive charge than at night [6]. The biological significance of this relationship should be discussed further.

Initially it should be noted that sunlight also causes positive electrification of illuminated objects [7], thereby masking variations in the positive charge of the earth’s surface due to its diurnal rotation [6]. Apparently, this camouflage does not allow us to separate the electrical effects associated with the daily rotation of the Earth from the electrical effects caused by sunlight. This camouflage is possible due to the lack of the majority of living organisms, including people, sensory organs capable of perceiving external electric fields. (As is known, such organs were found in some species of fish and, presumably, in some migratory birds.) For this reason, the electrical effects due to the Earth's daily rotation cannot be perceived by the majority of organisms, including humans.

Anyhow, variations in the positive charge of the Earth’s surface due to its diurnal rotation suggest that the existence of circadian rhythms is due not only to the action of visible light, in any case, to organisms that have an intestine. Obviously, such an assumption is very productive, since it allows one to explain the existence of circadian rhythms for organisms that are in the dark, including *Drosophila* [8-11].
It is clear that the existence of circadian rhythms that are dependent or not dependent on sunlight is due ultimately to the presence of intestinal gaseous hydrogen, through which there are electric fields between the intestine and the surfaces of the bodies of organisms that have intestines, including humans (Figure 2).

Let us now discuss the possible biological significance of the high penetrating power of hydrogen gas and its reducing properties [2,3]. Let us first consider the possible consequences of the penetration of gaseous hydrogen into the mitochondria and its presumed participation in the Krebs cycle (Figure 3).

**Figure 3:** This is the scheme of the Krebs cycle; for demonstration, the most satisfactory was the Russian version of the scheme. Pairs of the liberated hydrogen atoms are encircled by rings.

Since aqueous hydrogen gas is a strong reducing agent [2], it can restore mitochondrial NAD and FAD, which is quite natural, since
these substances are the most known biological hydrogen carriers, hence good acceptors of hydrogen atoms [4]. Since the participation of reactive hydrogen eliminates the need for numerous biochemical reactions occurring in the traditional Krebs cycle, the obvious result of the described restoration is the elimination of its usual substrates from the Krebs cycle (Figure 3) and, as a consequence, a more active synthesis of ATP.

Naturally, this interpretation of the cycle can give rise to the question: why this participation of hydrogen was not considered before? To answer this question, it is necessary to recall the history of bioenergetics. Historically, most bioenergetics processes were studied using suspensions of mitochondria or cells, which, naturally, were deprived of contact with intestinal gases and, consequently, with hydrogen gas. For this reason, the participation of gaseous hydrogen in the direct reduction of atomic hydrogen carriers was impossible. It is clear that under such conditions it was impossible to create bioenergetics, which considers the participation of gaseous hydrogen of intestinal origin in the direct chemical reduction of its pendants, in particular – mitochondrial.

Thus, since they were studied in media with other gaseous contents, it can be assumed that bioenergetics processes, studied in vitro, can fundamentally differ from the same processes occurring in vivo. It is clear that this is a common consideration, but it may be especially relevant for all organisms that have intestines, including humans and mammals. In particular, it is precisely with respect to such organisms that it may be necessary to rethink the exceptional glucose value for in vivo biological oxidation processes – it is entirely possible that glucose is much more important for cell and mitochondrial suspension free of hydrogen gas than for the same cells and mitochondria, that are in living organisms, having an intestine.

Let’s continue discussing the possible value of gaseous hydrogen of intestinal origin for mitochondria. Let us discuss, for example, its possible participation in the reduction of 8-OH-Gua, which is period-
ically formed in the mitochondrial DNA by the action of OH-radicals (Figure 4). This is important, since a number of senile human diseases are associated with the appearance of the same 8-OH-Gua in the composition of mitochondrial DNA [12,13].

![Guanine, G8OH*, 8-OH-Guanine](image)

**Figure 4:** This is a scheme for the oxidation of guanine by OH radicals [14]. It is believed that such oxidation of mitochondrial DNA causes a number of senile diseases [12,13].

Accepting this, it can be assumed that the same gaseous hydrogen of intestinal origin is able to react with 8-OH-Gua, which are part of the mitochondrial DNA, and restore them:

$$2H^* + 8\text{-OH-Gua} \rightarrow \text{Guaerd} + H_2O \quad (1)$$

Thus, given that damage to mitochondrial DNA by OH-radicals leads to the appearance of a number of senile diseases [12,13], this recovery can be an effective measure for preventing both these diseases and the aging process as a whole. Agree that this assumption is entirely logical, since the existence of an unoxidized mitochondrial DNA is a necessary condition for the normal functioning of mitochondria.

Now it seems quite natural to discuss the possible consequences of the effect of gaseous hydrogen of intestinal origin on nuclear DNAs, in particular on the activity of their genes and cellular proliferation.

It was shown that the activity of nuclear genes and the proliferation of mammalian cells are stimulated with reactive oxygen [15,16]. Taking into account the chemical properties of atomic hydrogen [2],
it can be assumed that in its presence the intracellular content of some forms of ROS will decrease. Thus, one can expect that its effect on the activity of nuclear DNA genes and cellular proliferation will be opposite to that of oxygen. Thus, an intestinal hydrogen gas may prove to be an effective suppressor of both nuclear genes and cell proliferation. In particular, it can be assumed that an increase in the intracellular content of hydrogen gas can have a therapeutic effect in those forms of cancer, the occurrence of which is due to oxidative damage to nuclear DNA [3,17-22].

In the aspect of the latter idea, it is also advisable to take into account the opposite effect of gaseous oxygen and hydrogen on the ability of water to interact with biopolymers, including DNA. So, you can make sure that water saturated with hydrogen does not hydrate biopolymers (Figure 5, left), and water saturated with oxygen – actively hydrates (Figure 5, right) [23,24].

**Figure 5:** This is how the starch swells in water saturated with hydrogen (left) and oxygen (right), at room temperature (~ 20 °C). Under these conditions, the starch does not swell in water saturated with hydrogen (left), and swells in water saturated with oxygen (right). After saturation with oxygen, water acquires the ability to penetrate through the plastic: the arrow shows how much the level of such water has decreased during the day [24].
(Very impressive is the behavior of DNA fibers deposited on the surface of water that is saturated with oxygen – within 1 to 2 seconds these fibers form a transparent surface film [23].)

In other words, biopolymers retain water saturated with oxygen and do not retain water saturated with hydrogen. Since the ability to retain water correlates with the rate of tissue growth, it can be expected that an increase in the tissue content of hydrogen gas will prevent the accumulation of water and inhibit their growth.

However, gaseous hydrogen can limit the growth of tissues, in particular – cancer, for one reason. As can be seen (Figure 5, right), water saturated with gaseous oxygen is able to escape from a closed bottle, penetrating through the plastic, and water saturated with hydrogen gas – no. If this extrapolation is correct, one can also expect that an increase in the content of hydrogen gas in the tissues may slow the penetration of water in them.

(It should be noted that a similar increase in the permeability of PET for water vapor induced by ionizing radiation was previously explained by oxidation of this plastic with the help of ROS formed as a result of such radiation [25]. If this extrapolation is permissible, it can be assumed that an increase in the permeability to water of both plastics and tissues is caused by the action of ROS. Agree, this assumption makes the antitumor role of the same gaseous hydrogen even more understandable. Perhaps, it can even reduce the harm of ionizing radiation, manifesting the properties of the radio-protector. The latter assumption is supported by the fact that organisms with a low percentage of water are less sensitive to ionizing radiation.)

In any case, it can be hoped that an increase in the content of hydrogen gas in tissues can stop both penetration and accumulation of water in them. In addition, it can also be expected that the same hydrogen gas can reduce the intracellular content of ROS, stopping both gene activation and cell proliferation, including tumor cell proliferation.
Of course, the accumulation of water in tissues can occur in other diseases, for example – in infectious. One can discuss the possible preventive effect of hydrogen gas on the example of the infection caused by the *Pseudomonas aeruginosa*.

So, it is known that the piocyanin, which is produced by *P. aeruginosa*, blocks the Krebs cycle by inactivating succinate dehydrogenase (Figure 3) [26], which is the regulatory enzyme of the cycle [4]. This inactivating effect can be explained by the oxidation of Fe$^{2+}$:

$$Fe^{2+} - e^{-} \rightarrow Fe^{3+} \quad (2),$$

which is a cofactor of succinate dehydrogenase [4], through oxygen activated by pyocyonin [27]. It can be expected that a hydrogen gas of intestinal origin can prevent such oxidation and, accordingly, blockade of the Krebs cycle:

$$Fe^{3+} + H^{*} (H^{+} + e) \rightarrow Fe^{2+} + H^{+} \quad (3).$$

As a result, it can reduce the toxic effects of *P. aeruginosa*, in general, which may be most noticeable in relation to the myocardium [26]. Thus, intestinal gaseous hydrogen can hypothetically prevent this infection by unlocking the Krebs cycle, which is possible due to the reducing properties of hydrogen gas in an aqueous medium. As can be seen from (3), the alkaline medium is more suitable for the realization of the reducing properties of hydrogen gas, in particular, the alkaline environment of the mitochondrial matrix where the Krebs cycle occurs [4]. Thus, it can be considered as a reducing agent which supplements the reducing properties of ascorbic acid, which is a donor of atomic hydrogen, i.e. a reducing agent, exclusively in an acidic medium.

It is clear that discussion of this topic can be continued. For example, it is possible to discuss the possible preventive action of intestinal gaseous hydrogen, hence – intestinal microflora, in relation to Parkinson’s and Alzheimer’s diseases, as well as – atherosclerosis, which is explained by the action of ROS [28-30]. It is also interesting to answer the question: why does a hydrogen gas penetrate through
the plastic (Figure 1), and water saturated with gaseous hydrogen - not (Figure 5)? Since the topic concerned may be important to many, I hope that these issues will receive coverage.

**Conclusion**

Considering the significant amount of gaseous hydrogen in the human intestine, as well as its physical and chemical properties, it is necessary to take into account the possible participation of hydrogen gas in the processes and reactions occurring in the human body.

Influencing the content and activity of the intestinal microflora, one can influence the production of intestinal gaseous hydrogen and, consequently, a number of processes occurring in the human body, including pathogenic.

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