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Radon transfer from water to milk

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ABSTRACT

Radon, as naturally occurring radioactive gas, is responsible for 50% of the total background radiations in human. Radon gas is able to enter to human body through eating and drinking. So, measurement of received radiation in the human body is essential. In this study, the presence of radon in milk and its dose was examined. This experiment was conducted using 12 Rayeni goats which have been categorized in a completely randomized design by 4 treatments and 3 replication (Treatment A = Radon-containing water + zero antioxidant, Treatment B = Radon-containing water + antioxidant, Treatment C = healthy water + antioxidant, Treatment D = healthy water+ zero antioxidant). The experiment was prolonged for 60 days. During the experiment the goats were milked every day. The samples were transferred to laboratory to determine the milk compounds and properties, as well as to measure its radon level. Presence of radon in milk was detected using Rad7 device. The averaged radon concentration in milk samples (for treatments A and B) receiving radon was about 126 Bq m^{-3}. There was no significant difference between protein. But there was a significant difference between the percentages of fat, lactose, total antioxidant capacity and the number of somatic cells. Radon did not change pH and Malondialdehyde contents of the treatments. We also determined annual received radon dose per person from drinking milk. It was different among age groups. Newborns were at higher risk of internal radon exposure from contaminated milk. Radon can enter the livestock milk. According to our findings, with, this radon amount in milk was not higher than the allowable level in valid resources for human health.

Key words: Radon, Milk, Antioxidant, Effective Dose.

INTRODUCTION

Radon is a chemical element with symbol Rn and atomic number 86. It is a radioactive, colorless, odorless, tasteless noble gas, occurring naturally as a decay product of uranium, thorium and radium in the soil. Stable isotope of ^{222}Rn, has a half-life of 3.8 days (Negarestani & Hashemi, 2011). Radon has harmful radiations for humans. There are natural and artificial radiations from radioactive substances in human environment. Human is exposed to radioactive radiations in both natural and artificial forms (Jalali Farahani & Zoolfaghari 2009). According to previous studies, less than 10% of annual radiations for one man, are from artificial sources and the rest are from natural ones (Charles 2001). Radon gas alone is responsible for over 50% of received natural radiations. The harmful effects of radon, such as cancer and genetic disorders, have been frequently reported by researchers (ICRP 2009). On the other hand, according to calculations, one/eight (1/8) of the received effective dose of all natural radiations for each person, comes from consumed food (Laxen 1981). Milk, has a special importance among types of foods, as it is one of the main nutritional sources for all human, specifically newborns – regardless of sex (Zain 2013). Some studies on dairy sciences, have reported the presence of radionuclides in milk (Ward 1989), but none of them is a comprehensive study on the radon presence in milk. Therefore, this study tried to investigate the presence of radon in milk and its impacts on milk compounds. Moreover, this study investigated the effect of antioxidants on the reduction of produced free radicals by radon (Mansourbahmani *et al.* 2013; Ghoochani *et al.* 2014). It was also aimed to determine the radiation dose per person from drinking radon-containing milk.

MATERIALS AND METHODS

This study was conducted to investigate radon transfer from water to milk and its effects on milk compounds, as well as to investigate the effects of a strong antioxidant on radon in milk. So that, 12 Rayeni goats were kept for 60 days. During the experiment, the goats were drunk radon-containing water provided from the Sirch hot spring in Kerman, Iran.

The radon level in water was recorded every day and its average amount was 8325 Bq m^{-3}. To ensure the inhalation of radon-free air, the goats were kept in an outdoor area. In addition, the vitamin E and selenium supplement was used, as a powerful antioxidant, for treatments B and C to determine the influence of antioxidants on negative impacts of radon (Sakoda *et al.* 2010).

This experiment included four treatments as follows:

Treatment A = radon-containing water + zero antioxidant

Treatment B = radon-containing water + antioxidant (vitamin E and Se)

Treatment C = healthy water + antioxidant (vitamin E and Se)

Treatment D = healthy water + zero antioxidant

Milk samples were obtained in three stages on the 50^{th}, 55^{th}, and 60^{th} days. After milking the goats, the milk samples were transferred to laboratory in sealed tubes in ice. Afterwards, the samples were investigated in terms of radon impacts on their compounds and properties (% fat, % protein, and % lactose; the number of somatic cells; total antioxidant capacity (TAC); malondialdehyde (MDA), and pH). Milk compounds were measured using Milkoscan device. Somatic cells (SC) were counted by Somatos system. TAC and MDA levels were evaluated using FRAP and Thiobarbituric acid spectrophotometry respectively (Mohammadi Abgharmi *et al.* 1999; Zarban *et al.* 2007).

The radon level in milk was detected by Rad7 system (Abojassim *et al.* 2014). Rad7 is a system designed by Durridge Company in USA, for the measurement of radon concentration. Besides, was studied the effect of a strong antioxidant (vitamin E and selenium) on the radon-contaminated milk compounds and properties. Vitamin E and selenium supplements was used according to the printed instructions on the medicine box.

Transfer coefficient of radon-to-milk was obtained using formula 1, which is widely being used to describe radionuclide passage to milk (Ward & Johnson 1986; Ward 1989).

$$\mathrm{Fm\ (d/kg)} = \frac{\text{radon concentration in milk (Bq/kg)}}{\text{daily radon intake(Bq/d)}} \qquad (1)$$

Daily radon intake was obtained from multiplying feedstuff concentration (Bq kg^{-1}) by feed intake (kg d^{-1}).

Water consumption per goat was considered 4 L (daily).

Since the density of water is very similar to that of milk, each kilogram of milk was considered equivalent to one kilogram of water

Annual effective dose per person from drinking radon-containing milk (126 Bq m^{-3}) was calculated, using formula 2 (Ahmad & Suhaimi Jaafar 2015; Mittal *et al.* 2016).

$$E = C.D.L.T \qquad (2)$$

Where E is annual effective dose (μSvBq^{-1}),
C is` radon concentration (Bq/m^3) and D is dose coefficient at different ages in the whole

body, which is equal to 23X10^{-3} μSvBq^{-1} for below 2 years, 5.9X10^{-3} μSvBq^{-1} for 2-16 years, and 3.5X10^{-3} μSvBq^{-1} for over 17 years; L = daily intake (1l/d) and T is time (365 days)

RESULTS

Radon in milk: This experiment was designed to obtain more accurate and comprehensive data concerning the radon transfer from drinking water to livestock milk. The results showed that ingested radon in drinking water can appear in milk (Table 1). Radon transfer coefficient to milk (in treatments A and B) was calculated according to formula (1) and was demonstrated in Table (1). Effect of radon on compounds of milk: A significant difference was observed among different treatments in fat content. There was a significant difference between the treatments in protein content too, which was lower in treatment D than the other treatments, suggesting that radon cannot reduce its content in milk. There was also a significant difference of lactose content in different treatments. So that, treatment A had the highest lactose content, while treatment D had the least respectively. In contrast, there was no significant difference in pH of different treatments (Table 2).

Investigation about the radon effect on somatic cells (SC), as an important indicator of milk quality, was showed a significant difference between the experimental treatments. Treatments A and B had greater number of somatic cells than treatments C and D (Table 2).

Table 1. The amount of radon in water and milk, and its transfer coefficient to milk.

Treatment	A	B	C	D
Radon in water (Bq m^{-3})	8325	8325	-	-
Radon in milk (Bq m^{-3})	121 a	131 a	000 b	000 b
F_m (d kg^{-1})	0.0036	0.0039	-	-

Different letters in each row represents the significant difference ($P < 0.05$).

Table 2. Qualitative specifications of milk in different treatments.

Treatment	A	B	C	D
Fat (%)	3.14 b	3.26 b	4.06 a	3.75 ab
Protein (%)	5.92	5.92	5.71	5.22
Lactose (%)	6.02 a	5.71 bc	5.90 ab	5.60 c
pH	6.70	6.65	6.66	6.60
SC (1000)	392.33 a	442.00 a	202.56 b	125.89 b

Different letters in each row represents the significant difference ($P < 0.05$)

Effects of vitamin E and Se on harmful effects of radon: In the present study, the effect of vitamin E and Se, was investigated as an antioxidant, on reduction of produced free radicals by radon in milk. Total antioxidant capacity index (TAC) was employed to examine the amount of free radicals in milk. Results showed significant differences in the treatments. The lowest, middle and highest total antioxidant capacity were observed in treatments A, B and C, respectively. According to these findings, radon can produce free radicals in milk (Table 3). Malondialdehyde (MDA): Results showed no significant difference between the treatments (Table 3). There was a correlation between somatic cells and radon concentration and also between somatic cells and total antioxidant capacity (Table 4).

Effective dose: The effective dose was measured using formula 2, the results were presented in Table 5.

Table 3. TAC and MDA in milk.

Treatment	A	B	C	D
TAC (mg dL^{-1})	1.30 d	1.89 c	3.07 a	2.53 b
MDA (µmole L^{-1})	1.86	2.00	1.73	2.10

Different letters in each row represents the significant difference (P < 0.05).

Table 4. Correlation coefficient.

Treatment	A	B	C	D
somatic cells and radon	0.38	0.38	_	_
somatic cells and total antioxidant capacity	-0.51	-0.51	_	_

Different letters in each row represents the significant difference (P < 0.05).

Table 5. The annual effective dose for each person in different ages caused by one liter milk.

Annual effective dose (µSv y^{-1})	A	B	C	D
newborns	1.015	1.099	00.00	00.00
children	0.260	0.282	00.00	00.00
adults	0.154	0.167	00.00	00.00

DISCUSSION

Milk is an important nutrient for humans and also an important radioactive carrier in human environment (Zain 2013; Abojassim *et al*. 2014). Kelly *et al.* (2000) reported radon presence in milk of livestock in regions where nuclear weapons were tested, or in near Chernobyl zone, and even in regions with high natural radiations.

Findings of the present study revealed radon presence in milk samples, such that it was detected in treatments A and B. This results were in accordance with reports of Lindell (1968), Kelly *et al.* (2000) and Abojassim *et al.* (2014).

In the present study, the ratio of radon in milk/radon in water was found to be 1:65; whereas Lindell (1968) reported this ratio as 1:40. The difference may be due to factors such as milking method, interval between milking and radon measurement, livestock activity, number of respirations, the type of lactating animal and finally experiment errors. The higher animal activity reported to increase radon excretion, through an increased respiration in lungs (ICRP 2015).

As shown in Table 2, treatment B which received radon-containing water, showed a higher radon concentration and also higher fat level than treatment A. It is in accordance with previous studies which reported that radon solubility in fat is as 100 times higher as in water (Lindell 1968).

Results showed that the presence of radon in treatments A and B increased the number of somatic cells in milk which are associated with quality and quantity of milk and its products (Ezzat Panah *et al.* 1999; Welenberg *et al.* 2002).

Somatic cells consist of neutrophils, lymphocytes, macrophages and dead epithelial cells in mammary glands and alveoli (Kondratov 2007). Typically, the number of somatic cells in milk is less than 200,000 cell mL^{-1}. However, the number of somatic cells elevates considerably due to some diseases (mainly mastitis) and also activity of defensive mechanisms. Since goats was examined from the aspect of mastitis infection and other diseases, so the large number of somatic cells in treatments A and B could be attributed to radon presence in udder cells. Results showed that the number of somatic cells and radon level were correlated with each other in treatments A and B (Tables 1 - 2) and their correlation coefficient was r = 0.38.

The cause of this phenomenon may be because of radon presence in udder tissue that causes damage in udder cells, and or may stimulate the immune system. However since there is no related reports, a precise and definitive conclusion requires conducting further experiments.

High concentration of free radicals and their derivatives are very harmful for living organisms, because these radicals have a destructive effect on biological macromolecules of the body. According to previous studies, exposure radiations may lead to the production of free radicals in body tissues (Mansour Bahmani *et al*. 2014). This phenomenon causes damage to body tissues both acutely and chronically. However, the production of free radicals in the body depends on the amount of received dose, dose intensity, organ sensitivity and diffusion of free radicals in the body (Asaad & Mohammad 2010). Mansourbahmani *et al.* (2014) also reported that the radon, can increase the number of free radicals in milk. Nowadays, there are various methods for investigating free radicals and antioxidants. One of these methods is oxidative stress index (such as amount of lipids peroxidation and total antioxidant capacity). However, direct measurement of free radicals is not common, because of their instability and also short life span (Rumley & Paterson 1998). The total antioxidant capacity is the outcome of an interaction between all antioxidant elements with different reduction potentials, which indicates overall strength of all known and unknown antioxidants in milk, plasma, etc. Greater antioxidant capacity is associated with more desirable outcomes (Shahsavari *et al*. 2014).

Comparison of results indicates that radon can increase the production of free radicals. The present results are in line with the report of Mansourbahmani *et al.* (2014), who reported an increased production of free radicals because of radon impacts. According to Table 3, vitamin E and Se supplement acted as an effective antioxidant by reducing the production of free radicals, because according to previous studies, antioxidant capacity in milk can be several times greater than the plasma concentration of mother (Ahmed *et al.* 2004). Comparison between the number of somatic cells and total antioxidant capacity showed a negative correlation among them (r=-0.51).

In the present study, we tried to investigate the malondialdehyde level and the effects of vitamin E and Se on it (because of high solubility of radon in fat and its effect on lipids oxidation). Malondialdehyde is an important product of lipid peroxidation (Tuter *et al.* 2001; Guentsch *et al.* 2008). Therefore, malondialdehyde is known as an index of lipid peroxidation in the lipid phase (Shahsavari *et al.* 2014). In contrast to total antioxidant capacity, the lower malondialdehyde is a better phenomenon. Considering the fact that the treatments do not have significantly difference in malondialdehyde level, so radon can not effect on fat oxidation. If a radioactive material enters the body, internal exposure begins in the body and continues as long as radioactive material remains in the body. The amount of radiation exposure in the whole body is expressed as "effective dose". This quantity considers not only the biological impacts of different radiations, but also those of different tissues (Jalali Farahani & Zoolfaghari 2009). Hence, calculating the received dose by the person is an important criterion and therefore, computation of the intake dose of radioactive substances is essential.

According to the United Nations Scientific Committee on the Effects of Atomic Radiation, the allowable level for natural background radiation is less than 2.4 mSv year^{-1}. In addition, radiation intake from drinking should not exceed 0.1mSv year^{-1} (Vucic *et al.* 2013). On the other hand, the effective dose allowable limit recommended by Unscear from radionuclides in milk is 200-800 µSv year^{-1} (Charles 2001).

Therefore, since the obtained effective doses in this study were lower than allowable limit, the consumption of milk containing this amount of radon would not have a harmful effect on health.

Also, results showed that harmful effects of radon within three age groups (newborns, children, and adults) was not the same. Newborns were the most sensitive in comparison with other groups.

CONCLUSION

Although, radon can transfer from drinking water to milk of livestock, but this amount of radon (126 Bq m^{-3}) is not a risk to humans.

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انتقال رادون از آب به شیر

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چکیده

گاز رادیواکتیو رادون به تنهایی مسئول بیش از نیمی از تشعشات دریافتی طبیعی انسان از محیط اطرافش است. این گاز قادر است از طریق خوردن و آشامیدن وارد بدن انسان شود. بنابراین، اندازه‌گیری پرتوهای رسیده به بدن انسان ضروری به نظر می‌رسد. در این مطالعه امکان حضور رادون در شیر و دوز دریافتی حاصل از آن در هر فرد بررسی شد. این آزمایش با استفاده از شیر دوشیده شده از ۱۲ بز نژاد راینی که در یک طرح کاملاً تصادفی با ۴ تیمار و ۳ تکرار دسته‌بندی شده بودند، به دست آمد (تیمار A = آب حاوی رادون + مقدار صفر آنتی اکسیدان، تیمار B = آب حاوی رادون + آنتی اکسیدان، تیمار C = آب سالم + آنتی اکسیدان، تیمار D = آب سالم + مقدار صفر آنتی اکسیدان). آزمایش ۶۰ روز به طول انجامید. در طول آزمایش، بزها روزانه دوشیده می‌شدند. نمونه‌های شیر برای تعیین ترکیبات و خصوصیات آنها و نیز میزان رادون موجود در آنها به آزمایشگاه ارسال شدند. حضور رادون در شیر با استفاده از دستگاه راد۷ مشخص شد. میانگین رادون در نمونه‌های شیر در دو تیماری که رادون دریافت کرده بودند، ۱۲۶/۰ $Bq\ m^3$ بود. در شیر تیمارهای مختلف بین درصد پروتئین تفاوت معنی داری وجود نداشت اما بین درصدچربی، لاکتوز ، ظرفیت تام آنتی اکسیدانی و تعداد سلول های سوماتیک تیمارهای مختلف تفاوت معنی دار وجود داشت. همچنین نتایج نشان داد رادون قادر به تغییر pH و مالون دی آلدهید در تیمارهای مختلف نیست. با انجام محاسبات مشخص شد دوز دریافتی هر فرد در یک سال، در اثر نوشیدن روزانه دو لیوان شیر حاوی رادون، در سنین مختلف، متفاوت خواهد بود. نوزادان بیش از دیگر رده‌های سنی در معرض پرتوگیری داخلی ناشی از شیر آلوده قرار دارند. بنابراین چنانچه رادون در آب آشامیدنی دام‌ها وجود داشته باشد، قادر به نفوذ در شیر خواهد بود، اما با توجه به محاسبات انجام شده و مقایسه آن با مقدار مجاز تعیین شده در منابع معتبر، این مقدار رادون در شیر نمی‌تواند برای انسان خطر ساز باشد.

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