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Quantitative measurement of the penetration of coconut oil into human hair using radiolabeled coconut oil

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INTRODUCTION

Applying oil to hair and skin is an age-old tradition in Asian and African countries. The traditional system of medicine in India, Ayurveda, has several formulations of oils (based mainly on coconut and sesame) with herbal extracts. These oils are supposed to benefit both hair and the hair follicle. Generally, these oils are applied as prewash hair dressings. This is also true of plain oils without any herbal actives. In either case, the hydrophobicity of the oil plays an important role in protecting hair from damage. Surface lubrication is the first level of defense against abrasive damage in grooming. A more significant factor is the protection of hair and especially the hair follicle from surfactant damage. Low-molecular-weight surfactants such as sodium lauryl sulfate (SLS) in shampoos can penetrate easily into the structure of hair and interfere with the formation of secondary valence bonds such as hydrogen bonds and salt linkages. This can weaken hair. On the positive side, penetrated oil can reduce the amount of water absorbed in the hair, leading to a lowering of swelling. This can result in lower hygral fatigue (repeated swelling and deswelling), a factor which can damage hair. The softening effect of moisture is replaced by the plasticizing effect of oil.

As far as the follicle is concerned, the oil can fill the gap between the hair and the follicle wall and prevent the penetration of the surfactant solution into the follicle. Surfactant molecules like SLS, when penetrated into the follicle, can interfere with the adhesion of follicular structures, leading to loosening of hair in the follicular cavity, ultimately leading to hair loss. Applying oil on a regular basis can eliminate follicular damage leading to hair loss. The overall effect is a head full of rich and long hair.

The first attempt to show the penetration of hair by coconut oil (CNO) was made by Ruetsch, Kamath, *et al.* (1). The method used was time-of-flight secondary ion mass spectrometry (TOF-SIMS), which was able to map the molecules of CNO in the cross section of hair treated with CNO. Although the method could show the depth of penetration, it was incapable of yielding quantitative (how much) data. Since then, the TOF-SIMS method has been used by Hornby *et al.* (2) to study the penetration of other vegetable oils.

However, the TOF-SIMS method, by its very nature, is qualitative. It cannot be used to determine the amount of oil that has penetrated into the hair. Therefore, the present work is aimed at developing a method that can provide quantitative data on the penetration of CNO into human hair, using radiolabeled CNO.

EXPERIMENTAL

MATERIALS

CNO was provided by Marico Limited, Mumbai, India. Solvents, such as alcohol, dioxane, and toluene, were of AR grade and were obtained locally. This work was done at Bhabha Atomic Research Centre (BARC) in Mumbai, India.

PREPARATION OF RADIOLABELED (^{3}H SUBSTITUTED (TRITIATED)) CNO

A known amount of CNO was dissolved in dioxane, and the solution was heated in the presence of tritium gas at 120°C for two hours in the presence of a catalyst (of proprietary composition). Following tritiation, the solvent was evaporated on a Rotovap, and the tritiated CNO (TCNO) was brought to a final volume of 1.5 ml with unlabeled oil. This oil mixture was used in all the studies presented in this communication.

HAIR TREATMENT

A 10-cm-long strand of Indian hair weighing 100 mg was soaked in 1.5 ml of TCNO. Hair specimens were taken from this sample after one and six hours for further analysis. Surface oil was determined with two single hair fibers, and penetrated oil was determined on five single hair fibers taken from the 100-mg sample. Measurements for each treatment time (one and six hours) were made in triplicate sets. The hair specimens were gently blotted on tissue paper soon after their removal from the oil-soaked strand in order to remove the extraneous oil. The approximate weights of two and five hair fibers were 1.22 mg and 6.1 mg, respectively.

RADIOACTIVITY MEASUREMENTS

A unique property of tritium is that it is a beta emitter, and therefore, to register its emission it has to be in direct contact with the scintillation fluid. This means that the TCNO inside the hair is not registered. This enables the measurement of substantive surface oil separately. In a typical measurement two hair fibers were immersed in 10 ml of the scintillation fluid and placed into the counter (Hidex, efficiency 32%). The counts per minute (CPM) were recorded.

For the determination of total oil in the hair (surface oil plus penetrated oil), five hair fibers were solubilized in 400 μ1 of 10% NaOH at approximately 70°C for one hour or until the solubilization of the sample was complete. Five microliters of the hydrolyzed hair solution was added to 10 ml of the scintillation fluid, and the CPM was recorded after the solution was placed in the scintillation counter (Hidex).

RESULTS

STANDARDIZATION OF THE RADIOACTIVITY OF THE ORIGINAL TCNO

Twenty microliters of the 1.5-ml original TCNO sample was diluted with 10 ml of toluene, of which 20 μl was added to 10 ml of scintillation fluid and placed in the Hidex scintillation counter, which gave a CPM of 45,000. Radioactivity is expressed in units of curie (Ci), which refers to decay of 3.7×10^{10} per second (or 2.22×10^{12} per minute) CPM. The radioactivity of the original oil is given by:

$$\frac{45{,}000\ \text{CPM} \times 10{,}000\ \mu\text{l}\ (\text{toluene}) \times 1500\ \mu\text{l TCNO}}{20\ \mu\text{l} \times 20\ \mu\text{l} \times 2.22 \times 10^{12}\ (\text{CPM/Ci}) \times 0.32\ (\text{efficiency of Hidex})}$$

which is 2.4 mCi/1.5 ml or 1.6 mCi/ml of TCNO. This number will be used to convert CPM into the volume of TCNO in the hair specimens.

MEASUREMENT OF SURFACE OIL

In a typical measurement, two hair fibers were immersed in 10 ml of the scintillating fluid and placed into the Hidex counter. A CPM value of 106,458 was recorded. From this number we can calculate milligrams of oil in the hair as shown below. Please note that from the definition of curie, 1 μCi = 2.22×10^6 CPM:

$$\frac{(106{,}458\ \text{CPM}) \times 0.92\ (\text{sp. gr. oil}) \times 100}{(2.22 \times 10^6\ \text{CPM}/\mu\text{Ci}) \times 0.32\ (\text{eff. of Hidex}) \times (1.6\ \mu\text{Ci}/\mu\text{l}) \times (1.22\ \text{mg, wt. of hair})}$$

The above calculation gives a value of 7.1%. The calculation can be abbreviated as follows:

$$\text{Wt. \% surface oil} = \left((\text{sample CPM}) \times 80.9 \times 10^{-6}\right) \Big/ (\text{wt. of hair})$$

MEASUREMENT OF TOTAL OIL

In this procedure a known weight of TCNO-treated hair is solubilized in 400 μl of 10% NaOH and a 5-μl sample is used to get the scintillation counts. The total amount of oil can be calculated exactly as above using one additional factor: (400/5) = 80. Therefore,

$$\text{Wt. \% total oil} = \left((\text{sample CPM}) \times 80.9 \times 10^{-6} \times 80\right) \Big/ (\text{wt. of hair})$$

For a CPM of 47,100 for one of the samples, the wt.% total oil is 50%. Subtracting the surface oil from the total gives the oil penetrated into the fiber. The amount of surface oil in the sample taken for the total oil measurement can be calculated by the following formula:

$$\frac{\text{Wt. \% surface oil} \times \left(\text{wt. of hair for total oil}\right)}{\left(\text{wt. of hair for surface oil}\right)}$$

This is given in Table I. Data for surface and penetrated oil are summarized in Table I. Percentages are based on the weight of the treated hair.

DISCUSSION OF RESULTS

The results in Table I show that the method can determine surface oil. The values for surface oil are slightly on the higher side, which indicates that just dabbing with absorbent paper does not remove all of the surface oil. It probably cannot remove oil residing at the scale edges. The bulk oil amounts are unexpectedly high. It is not possible to have such high values for the total oil without the swelling of the fiber, and CNO does not swell the hair fiber. The high values obtained for the bulk oil in this study suggest that most of it is indeed surface oil. If we correct for the surface oil in the sample taken for the total oil measurement (column 4 minus column 6), then the results for the penetrated oil appear to be more reasonable, especially for the samples treated for one and six hours.

CONCLUSIONS

The work presented in this communication shows that radiolabeling with tritium can be a suitable method for the quantification of the oil penetrated into hair. The method can distinguish between the surface deposited oil and the oil absorbed into the bulk of the fiber. This would suggest that the method can be used to quantify other actives that are deposited mainly on the surface of hair. The method can be further refined by extracting the hair sample briefly in a solvent like hexane to remove the surface oil. By doing this prior to analysis, we can confirm the validity and internal consistency of the surface, total, and penetrated oil results obtained by this method. The researchers plan to do this work in the near future.

Table I
Distribution of TCNO in Human Hair (wt.% based on hair) Treated with TCNO for One and Six Hours

Sample name	CPM Total oil	CPM Surface oil	Wt.% Total oil	Wt.% Surface oil	Wt.% of surface oil in the total oil test sample	Wt.% Penetrated oil
1A	47,100	106,458	50.0	7.1	35.5	14.5
1B	45,300	80,000	48.5	5.4	27.0	21.5
1C	45,200	—	48.4	—	—	—
6A	61,000	116,000	65.3	7.8	39.0	26.3
6B	62,000	138,000	66.4	9.2	46.0	20.4
6C	62,000	133,000	66.4	8.9	44.5	21.91

All percentages are based on the weight of the treated hair.

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