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Treatment for Dry Skin and an Unpleasant Smell: Development of a Moisturizer with Deodorant for Maintaining a Good Skin Condition

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ABSTRACT

Background Many people from every generation report having dry skin, particularly older adults who use incontinence garments. Such older adults experience problems with not only dry skin, but also various aging-related malodors. Common problems such as dry skin and malodor can affect the physical and mental condition of many people around the world; therefore, these problems need to be solved. Accordingly, we aimed to develop a moisturizer that also contains deodorant to help prevent the occurrence of aging-related malodor. **Methods** To develop a moisturizer, we selected different mixtures of four candidate materials to reduce the occurrence of dry skin and malodor. We also investigated the effectiveness of three mixtures for reducing malodor using a detector tube and a human sensory test, and monitored the preservability of the mixtures for 6 months. **Results** Among the candidate materials, we selected five, including petrolatum and liquid paraffin (ointment base), polyacrylic acid, lysine (deodorizer), and Japanese cypress (deodorizer and preservability agent). All of these materials showed effectiveness for reducing malodor in the detector tube study and human sensory test. No particular problems in terms of the preservability of texture, color, or bacteria were found. In addition, some mixtures markedly reduced malodor and were highly preferred in the human sensory test. **Conclusion** The moisturizer with a malodor-reduction function developed in this study showed good preservability without any synthetic preservatives. In addition, it was highly preferred in the human sensory test. Therefore, it could be expected to help solve the common problems of dry skin and malodor for many people around the world.

Background

Dry skin is one of the most common problems reported by people from every generation [1, 2]. Even in younger generations, many people experience the uncomfortable condition of dry skin [3–5]. Severe cases of dry skin, along with various other problems, are more commonly seen in older adults. Considering the rapid aging of the population around the world, the issue of dry skin could become one of the most common problems for older people in their everyday life. Older people aim to live a life with good physical and mental status, so having a good skin condition is an important aspect of living that directly affects their feelings and emotions. In addition, particularly among older adults who are confined to bed, chronic dry skin tends to cause endless troubles, including itching, peeling, and more serious conditions such as infection and pressure ulcers. On the other hand, from the caregiver point of view, maintaining the health and hygiene of bedridden older adults is an important issue [6, 7]. Older adults who use incontinence garments often experience odors associated with aging and urine that affect people around them. Therefore, dry skin and odor problems tend to coexist among older adults. An effective solution to these skin-related problems could therefore benefit not only older adults, but also those close to them who are involved in daily care [8–10]. Given the present background, in the present study, we aimed to develop a new sustainable and additive-free moisturizer that could help treat or prevent dry skin and malodor [11, 12]. This pleasant-smelling moisturizer could also be used by anyone in the general population who wants to use a moisturizer that includes deodorant in daily life. Even when limited to the issue of dry skin (e.g., atopic dermatitis), many people around the world who experience dry itchy skin, from infants to older adults, would welcome the development of an effective moisturizer that offers such advantages.

Methods

Selection of materials and study of material nature

First, we selected materials for use in a moisturizer aiming to improve the conditions of dry skin and malodor associated with aging and urine. Several candidate materials were reviewed based on data from previous experiments, and then a selection was made. The selected material was investigated individually in substance and sensory tests (Table 1).

Second, to make the basic components of the moisturizer, we evaluated components from among the moisturizer candidates and studied their nature based on evidence from substance

study data. Several different ratio components were developed, from which, a feasible candidate was selected. After we made the moisturizer mixture, we conducted a human sensory test (n = 10; 4 males, 6 females; mean age 24.2 ± 15.4 years) and evaluations using a visual analogue scale (VAS; Tables 2 and 3).

Third, we tested the preservability of the moisturizer's basic components for about 6 months and the nature of the moisturizer every 2 months for 6 months. In addition to monitoring preservability, we also performed sterility tests on mixtures C-2 and D (Tables 2 and 3) and the control (white petrolatum; Table 3) immediately and at 1 and 2 months after the moisturizer was developed. The moisturizer was smeared on blood agar and Sabouraud's agar media with a sterile cotton swab. The blood agar medium was then incubated at 35 °C and on Sabouraud's agar medium at 25 °C. Both media were incubated for 1 week to check for the presence of microorganisms.

Results

Selection of materials and study of material nature

Ointment base

Mineral oil, liquid paraffin, and white petrolatum were selected as candidates for the ointment base (Table 1). Mineral oil is commonly used as baby oil, but its viscosity is not appropriate for creams or ointments. Because we needed to devise a texture consistent with a cream or ointment, as well as a material that could be mixed with other items, we selected petrolatum among these three items, which, according to the Japanese Pharmacopoeia, is typically used as an ordinary moisturizer base, especially for people with sensitive skin. In addition, we selected liquid paraffin to mix with petrolatum to derive a different texture. In a preliminary study, petrolatum and liquid paraffin could easily be mixed at a flexible ratio. The characteristics of petrolatum and liquid paraffin are shown in Table 1. Both types had a smooth texture and no smell or particular color, and were easily mixed with other materials.

Items for reducing malodor associated with aging and urine

Based on data from previous studies **[13–15]**, we selected candidates to reduce malodor. The selected items and their characteristics are shown in Table 1. There were two candidates for reducing malodor associated with urine (i.e., ammonia). Citric acid is used in foods such as soup, as well as toothpaste and other cleaning items, but tends to cause dry skin **[16]**.

Polyacrylic acid is used in foods, cosmetics, and supplements, and is also considered safe to use as a base for creams and ointments. Because citric acid can cause dry skin, polyacrylic acid was considered more suitable for use in our moisturizer. The anionic polar group of polyacrylic acid also makes possible the electrostatic adsorption of ammonia (Fig. 1). In addition, under a pH of 4–5, the nature of polyacrylic acid (local acidification) is useful because it accelerates the decomposition reaction of nonenal (responsible for aging-related malodor). Therefore, a malodor-reducing effect was seen even when the proportion of lysine was low (C-2, D).

Thus, only one candidate remained for mainly reducing aging-related malodor. Lysine is an essential amino acid used in various foods and supplements that is also considered safe to use in moisturizers. Lysine is also reported to reduce aging-related malodor (nonenal) via a nucleophilic addition reaction and accelerated with a polyacrylic acid reaction (Fig. 1) **[15]**. However, lysine itself is very hard and has a rough texture; therefore, it is not easily mixed with other materials (Tables 1 and 2, Fig. 2).

Items for natural sterilization

Isopropyl methyl phenol has no scent and is commonly used in hard soaps, liquid soaps, and ointments (Table 1). Formulations have an upper limit when used on the mucous membranes. On the other hand, Japanese cypress (an essential oil) and hinokitiol (an oil extracted from Chamaecyparis taiwanensis) have a fresh forest scent and not only express sterilization properties, but also help prevent tick bites and infections caused by methicillin-resistant Staphylococcus aureus [13, 14]. Both Japanese cypress and hinokitiol have a similar nature [17–19]. In a preliminary examination, no difference in smell or texture was found between Japanese cypress and hinokitiol, so both were used in the evaluation. Hinokitiol is more expensive than Japanese cypress, so Japanese cypress could be a better candidate for use in a practical moisturizer (Table 1).

Components of the moisturizer candidates and their nature

To evaluate the deodorization effects of nonenal and ammonia, a gas detector tube and sensory test was conducted on the control (white petrolatum), Japanese cypress (A), lysine (B), and lysine and polyacrylic acid ointment (C-2) groups (Table 3). First, using different proportions of petrolatum, polyacrylic acid, lysine, and Japanese cypress (similar to hinokitiol), several moisturizers were made (Table 2). To identify the best mix, experimental

and sensory tests were conducted. Table 2 shows the proportion of the five different mixtures. Mixture A, which contained only Japanese cypress, showed a similar texture to white petrolatum and had a fresh scent. Among mixtures B–D, B, and C-1, which contained high proportions of lysine, were not mixed easily and had a texture inappropriate for use as a moisturizer (Fig. 2). Therefore, mixtures A, C-2, and D were considered feasible candidates for a moisturizer. Mixture D was an alternative for C-2 because it contained 15% w/w of liquid paraffin and appeared to melt more easily.

As for test of deodorization (nonenal and ammonia), mixtures A, B, and C-2 were evaluated using a detector tube and a VAS sensory test (Table 3). Mixture C-2 achieved the best results for both nonenal and ammonia; therefore, mixtures C-2 and D were considered feasible candidates for use in a moisturizer. In addition, the evidence shown in Figure 1 regarding the reaction also showed a good effect. All participants in the sensory test commented that the aroma of Japanese cypress was good to use in a moisturizer.

Evaluation of moisturizer preservability

Table 4 shows the results of an examination of stability in room air. Feasible candidate mixtures C-2 and D showed no particular change in appearance, smell, or texture after 6 months, which was similar to the Japanese cypress (A) and control (white petrolatum) mixtures. Although neither mixture C-2 nor D contained any additional substances to aid preservability, no particular change was seen after 6 months (Table 4). The tests were performed on mixtures C-2 and D and the control immediately after the moisturizer was developed. Every moisturizer was then smeared on blood agar and Sabouraud's agar media using a sterile cotton swab 1 and 2 months later. The blood agar medium was incubated at 35 °C and Sabouraud's agar medium at 25 °C. Both media were incubated for 1 week to check for the presence of microorganisms. No colonies were observed on either medium (data not shown).

Discussion

The need for medical care and life support for older adults is rapidly increasing in not only developed, but also developing countries **[20–23]**. This means that affordable and feasible medical care needs to be kept in mind for every situation. Support for older adults consists of various aspects, including advanced medical care, regular drug therapy, mental care, and care for maintaining a comfortable life **[24–26]**. Although the level of the medical-related care

might differ depending on the economic and political status of each country, helping to ensure a comfortable life is a universal goal undertaken by the economic and social efforts of any countries. Skin care products and deodorants are basic elements of everyday life, and thus contribute greatly to ensuring a more comfortable life for older adults **[27–32]**.

On the other hand, deodorant is becoming increasingly important in societies with diverse values and lifestyles, indicating that people of all ages want to be considerate regarding unpleasant odors **[33–35]**. Particularly, in care settings for older adults, reducing aging-related malodor has mainly been the task of the care staff **[36]**. Hardly found the item of actually absorb uncomfortable smell itself. Therefore, we attempted to develop a moisturizer that could actively absorb and reduce aging-related malodor, with a simultaneous focus on the issue of dry skin (e.g., atopic dermatitis) because it is becoming an increasingly serious issue around the world **[37–40]**. Problems such as dry skin and malodor commonly affect the physical and mental condition of many people around the world, across generations [40]. Although the causes of dry skin vary, every person with dry skin desires a cream or ointment that is less allergic, pleasant to use, and affordable. Therefore, we aimed to develop a moisturizer containing deodorant through the selection of various combinations of ingredients and compositions.

Table 1 shows the nature of these ingredients, with every item having some role and all helping to ensure the safety of the product when used in cosmetics and ointments. These items can reasonably be considered to be less allergic for the skin. As shown in Table 1, we selected four items: white petrolatum, polyacrylic acid, lysine, and Japanese cypress. Based on the nature of each item, different moisturizers were developed, all of which reduced malodor. However, it was necessary to identify combinations that could afford a more appropriate texture. Therefore, we used different ratios of moisturizer mixtures and tested them based on several indicators. Table 2 shows the results of four different moisturizer mixtures. In practice, some mixtures were difficult to make because of a poor texture. For example, a large amount of lysine was difficult to mix in an appropriate ratio with other materials (Fig. 2), making it unfeasible for use as a moisturizer. Therefore, considering texture, usefulness, and feasibility, mixtures C-2 and D were considered suitable candidates. We then attempted to mix lysine with liquid paraffin, followed by other materials. These mixtures were very useful for reducing the roughness of lysine. Moreover, adjusting the amount of liquid paraffin made it possible to develop mixtures with various textures.

After obtaining samples of mixtures with various textures, we conducted a human sensory test using a VAS. The results showed that mixture C-2 achieved the best score among the four different mixtures. The malodor-reducing mechanism was mainly explained by the reaction shown in Figure 1. In addition, based on the results of the sensory test, the aroma of the Japanese cypress mixture was very pleasant in the moisturizer, as it was preferred by all participants.

Japanese cypress was highly evaluated for its bacteriostatic action and refreshing, fresh forest-like scent, which improved the quality of the mixture and exhibited a masking effect on nonenal and ammonia. Thus, it has been used as a vermicide and preservative for various items, including cosmetics, furniture, and homes **[41–44]**. Even without other additional preservatives, mixtures such as C-2 and D demonstrated high preservability. In fact, no change in appearance, aroma, or texture was observed after 6 months (Table 4, Fig. 3).

Moreover, no particular change in surface color or moisture resulting in mold was seen in the sterility test. Similar findings in a petrolatum-only control based on microscopic observations. Petrolatum is commonly used as ointment, and has been found to show no particular changes for 2–3 months **[45]**. Therefore, even without additional substances, mixtures C-2 and D demonstrated preservability for several months.

In the present study, we were able to create a feasible and effective moisturizer containing deodorant. More clinical tests (e.g., allergy, usability, preference) should be conducted in the future.

Conclusions

Although dry skin is a commonly reported problem, it is often treated ineffectively. In addition, malodor has remained a problem across generations. Considering that a good skin condition and less malodor could reduce stress and promote more comfortable experiences in everyday life, the successful development of a feasible moisturizer/deodorant with a fresh scent, such as that described in the present study, is urgently needed.

Availability of data and materials

All data presented in this paper were obtained from experiments conducted by the authors; no other sources of data are available.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceptualization, K.S., methodology, K.K., J.F., K.S.; software, K.S., K.K.; validation, K.K.; formal analysis, K.S., K.K.; investigation, K.S., K.K.; resources, K.S.; data curation, K.S., K.K., H.U.; writing—original draft preparation, K.S.; writing—review and editing, K.S., K.K.; visualization, K.K.; supervision, K.S.; project administration, K.S.; funding acquisition, K.K. All authors have read and agreed to the published version of the manuscript.

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Figure legends

Fig1 Chemical reaction affect better inference for reduce odor

Fig2 The picture shows the mixture of Lysine. It is hardly mix with petrolatum

Fig3 The real appearance of Lysine mixture

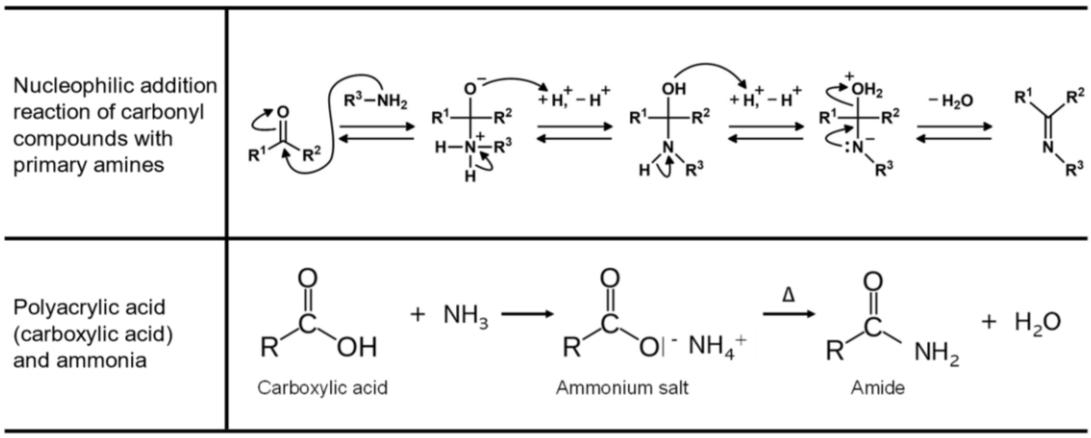


Fig. 1 Chemical reaction of carbonyl compounds with primary amines

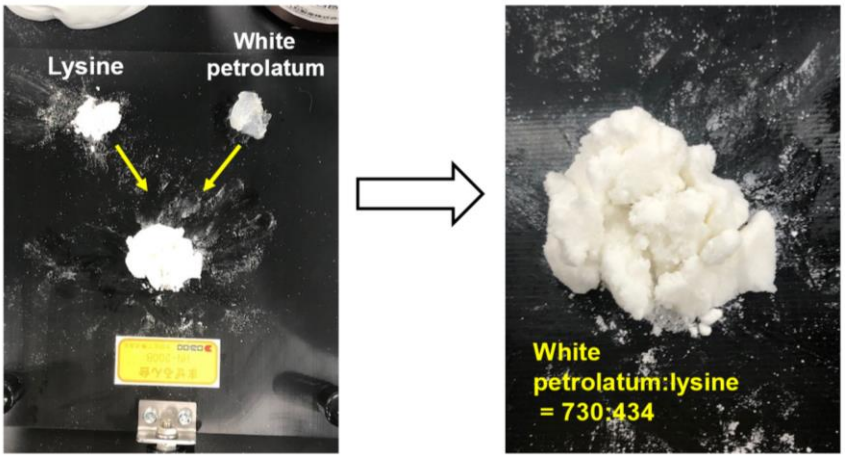


Fig 2. Appearance of the ointment mixed with a large amount of Lysine.

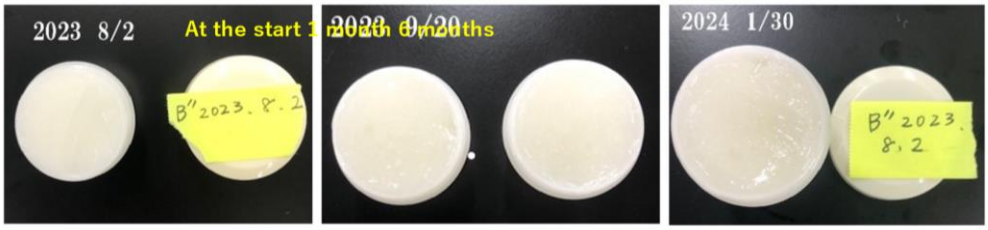


Fig. 3 Results of the stability test: appearance of ointment (mixture D)

Table 1 Ointment formulation ingredients

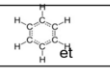
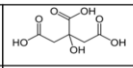
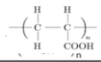
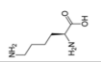
Ointment base	Essence	Structural formula	Characteristics	Official specifications
Mineral oil	Aromatic hydrocarbons, paraffinic hydrocarbons, naphthenic hydrocarbons		Viscosity (hardness) like cream is desired, so it is difficult to formulate	Japanese Pharmacopoeia
Liquid paraffin	Alkane with 20 or more carbon atoms	C_nH_{2n+2}	White Vaseline-based ointment, mixed to obtain different grades of viscosity	Japanese Pharmacopoeia
White petrolatum	Isoparaffins and alicyclic hydrocarbons (cycloparaffins, naphthenes)	C_XH_Y X=15~20	Commonly used for ordinary moisturizer	Japanese Pharmacopoeia
Additive or active ingredient (deodorization and antibacterial)				
Citric acid	An organic compound found in citrus fruits, one of the hydroxy acids		Tends to cause a dry skin condition. If inhaled, may cause coughing, shortness of breath, and sore throat	Japanese Pharmacopoeia
Polyacrylic acid [Carboxy vinyl polymer]	Highly safe water-soluble polymer		Thickening property, inhibition of fungal growth, and adsorption of putrefactive odors such as ammonia	Quasi-drug Ingredient Standards [Japan]
Lysine [L-lysine hydrochloride]	Contains an α-amino group, α-carboxylic acid group, and a side-chain lysyl ($(CH_2)_4NH_2$)		Chemical conversion of unsaturated aldehydes [2-nonenal] to nonvolatile (neutralization reaction)	Japanese Pharmacopoeia
Isopropyl methyl phenol	Phenol induction Used as a disinfectant, antiseptic, and mold inhibitor		There is an upper limit to the formulation when used on mucous membranes [upper limit: 0.1 g/Cosmetics 100 g]	https://www.mhlw.go.jp/stf/english/index.html
Japanese cypress	Fragrant oil containing unsaturated seven - membered ring compounds found in cedar (natural antibacterial material)		Aroma effect (odor mitigation) and antibacterial and antiviral effects	https://www.rinya.maff.go.jp/tohoku/

Table 2 The five formulations used in the present study [w/w %]

Formulation		White petrolatum	Hinokitiol	Japanese cypress	Lysine	Polyacrylic acid	Liquid paraffin
		Ointment base	Aroma, antiviral effects [contains hinokitiol]		Nonanal deodorization	Ammonia deodorization	Thickener
A	Japanese cypress	99	1				
B	Lysine (3) ointment	97			3		
C-1	Lysine (3), polyacrylic acid ointment	90	1		3	6	
C-2	Lysine (1), polyacrylic acid ointment	92.5		1.5	1	6	
D	Five-in-one ointment	76.5		1.5	1	6	15

Notes: Odor and contact sensation of prescription ingredients of each ointment formulation

A Japanese cypress : good fresh scent
B Lysine (3) ointment : rough texture
C-1 Lysine (3), polyacrylic acid ointment : very rough texture
C-2 Lysine (1), polyacrylic acid ointment : good texture and fresh scent
D Five-in-one ointment : good cream texture and fresh scent

Table 3 Deodorization evaluation of nonenal and ammonia

Prescription		Nonanal		Ammonia	
		Sensory test VAS: Mean/R	Detector tube concentration (%)	Sensory test VAS: Mean/R	Detector tube concentration (%)
	Control (white petrolatum)	10.0 / (10.0–10.0)	0.300	10.0 / (10.0–10.0)	0.250
A	Japanese cypress ointment	7.1 / (4.4–10.0)	0.250	-	-
B	Lysine (3) ointment	4.7 / (2.0–10.0)	0.000	8.5 / (7.1–10.0)	0.220
C-2	Lysine (3), polyacrylic acid ointment	4.6 / (0.0–10.0)	0.100	5.9 / (3.0–7.0)	0.180

Notes: Test sample: nonanal: 0.038 mg in 300 mL triangle meyer (60 μL diethyl ether solution of 0.0045 mol/L nonanal); ammonium: 17 μL 5% ammonia solution in 300 mL triangle meyer
Sensory test: 0.93 g of the ointment sample was applied to a triangular maier containing the odorant; 30 min later, a panel of 10 people smelled the odor and assigned a visual analog scale (VAS) grade. Unbearable odor = VAS 10 cm
Gas detector tubes for unsaturated aldehyde: Gastec Detector Tube M91 for ammonia : Gastec Detector Tube M (ammonia)
Free comments from 10/10 subjects: I prefer the scent of the Japanese cypress.

Table 4 Evaluation of stability (appearance, aroma, texture)

		Storage period (room temp)	Stability test items		
			Appearance	Smell of cypress	Texture (roughness)
C-1	Lysine (3), polyacrylic acid ointment	At start time	Slightly yellowish white	Almost no smell	Roughness is present
		1 month	Yellowish white	Moderate odor	Slightly rough
		2 months	Yellowish white	Moderate odor	Slightly rough
		6 months	Yellowish white	Moderate odor	Slightly rough
C-2	Lysine (1), polyacrylic acid ointment	At start time	Slightly yellowish white	Moderate odor	Slightly rough
		1 month	Same as at start	Same as at start	Same as at start
		2 months	Same as at start	Same as at start	Same as at start
		6 months	Same as at start	Same as at start	Same as at start
D	Five-in-one ointment	At start time	Slightly yellowish white	Moderate odor	Slightly rough
		1 month	Same as at start	Same as at start	Same as at start
		2 months	Same as at start	Same as at start	No roughness
		6 months	Same as at start	Same as at start	No roughness

Notes: Control sample (white petrolatum): No change in appearance was seen after 6 months.