

Microbial Mechanism of Body Odour and Cosmetic Approaches for Odour Prevention

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Abstract—The issue of body odour is more complex than simply the secretion of sweat from the skin; rather, odour is produced as a result of biotransformation of odourless sweat precursors by skin microbes. Specifically, bacteria within the skin microbiome in the axilla have the capacity to convert apocrine and eccrine gland odourless precursors to odorous compounds through C-S lyases, lipases and aminoacylases. Thioalcohols such as 3-methyl-3-sulfanylhexas-1-ol, short chain fatty acids such as 3-methyl-2-hexenoic acid and steroids such as androsterone have been identified as the most potent contributors to axillary odour. Odour production is subject to individual variation; it is affected by the genes an individual carries (through polymorphism), as well as by diet, hormonal state and age. Cosmetic and drug companies approach the issue of body odour with a combination of various techniques, most notably the killing of all skin microbes; however, this kills off both beneficial commensal microbes and malodour producing microbes. Future solutions are more targeted at inhibiting the enzymatic pathways that lead to body odour as well as manipulating skin microflora. The following review outlines what is known regarding the mechanisms of the formation of body odour by skin microbes and critically appraises different cosmetic solutions in preventing while identifying a number of key research questions and future areas of research.

Index Terms—axillary microbiome, body odour, *Corynebacterium*, *Staphylococcus*, thioalcohols, volatile organic compounds, deodorant, antiperspirant, skin microbiome, probiotic cosmetics

I. INTRODUCTION

The pervasive and universally experienced nature of body odour (specifically axillary body odour) has significant social, psychological, and commercial consequences. Although commonplace, the mechanistic understanding of the production of body

odour has undergone an evolutionary shift in the past thirty years. Initially it was theorized that sweating directly led to body odour, however, scientific research has moved towards the idea that our resident skin microflora is predominantly responsible for generating body odour. Sweat itself contains no volatile compounds that contribute to the smell of body odour, but on exposure to our skin flora and within the body odour producing environments found in skin fold regions, these compounds are metabolized to volatile organic compounds (VOCs) that our noses detect as body odour. The worldwide market for deodorant and antiperspirant products has reached over 25 billion dollars a year, illustrating how great the consumer desire is to manage body odour. Many commercial products utilize antimicrobial compounds that do not take into account skin microbial ecology and whose effect on long-term Commensal microbes is largely unknown. Issues with the safety of both aluminium-containing antiperspirants and preservatives such as triclosan have led to the increased interest from consumers for evidence-based products that are not detrimental to our skin microbes. Body odour is mainly produced in the axilla due to the warm, occluded microenvironment, the abundance of apocrine glands, and a unique bacteria population predominantly made of *Staphylococcus* and *Corynebacterium* species. These species produce specific enzymes that take the odourless precursors secreted from sweat glands and metabolize them into Volatile Organic Compounds responsible for the characteristic smell of body odour. The knowledge of these processes at a molecular level is crucial for a rational development of future cosmetic interventions targeting body odour. This review provides a thorough integration of the literature on the bacterial mechanisms of body odour generation (focusing on

the axillary microflora, biochemical pathway, important Volatile Organic Compounds, and the individual variation of each source) and discusses new and existing cosmetic strategies for odour prevention, emphasizing their targeted microbial/biochemical mechanisms, their efficacy, and safety.

II. THE SKIN MICROBIOME COMPOSITION AND ECOLOGY

2.1 Cutaneous Microbiome

Human Skin is largest surface area covering organ it is composed of various microorganism such as bacteria, fungi, virus parasites and archaea, which are responsible for the unpleasant odour by decomposition of the sweat components which is exhaled by eccrine and apocrine glands. It is all dominating oily and subconscious sites like the back, forehead for arm, dry areas of the body and moist sites such as armpit supports growth of *Staphylococcus* and *Corynebacterium*. This skin microbiome plays a crucial role by providing competitive exclusion against invading pathogens and modulating local responses and by maintaining acidity of the skin. If these microbiomes are damaged could be responsible to proneness to bacterial skin irritation or skin inflammation.

2.2 Axillary Microbiome

Axilla (Under arm) represents Microenvironment which is favourable for bacterial colonization like compatible warm temperature, high humidity and exclusion. This area contains high volume of apocrine glands in comparison of eccrine glands. In this area there is various type of bacterial colonies identified like *Staphylococcus* and *Corynebacterium* which is associated to the production of sweat and the decomposition of sweat components leads unpleasant smells in the group of bacterial species includes *C. Striatum*, *C. Xerosis*, *C. Jeikeium*, *S. Epidermis* is contributes minimal odour but *S. Haemolytic* and *S. Hominies* leads to unpleasant thioalcoholic smell.

2.3 Factors that shaping Axillary Microbiome Composition

Axillary Microbiome's nature of growth is very dynamic and can be influenced by foreign activities. Like Shaving, use of antiperspirant and deodorant, Diet, Hormonal changes and status, age dependant

physiological changes in the human body. Shaving removes a portion of the skin which leads the changes of microenvironment and it causes change in bacterial community composition. Use of antiperspirant reduces the sweat secretion and decrease moisture and humidity level which can lead the decreases level of microbial growth, Antimicrobial deodorant reduces Gram-positive bacteria, It may lead increased abundance of gram positive bacteria. Hormonal changes like menstrual cycle leads the variation in microbiome growth changes specially androgen hormones stimulate apocrine sweat glands and increased gland activity releases more odour precursors. Aging changes plays huge role in sebum composition and it leads qualitative changes and structural changes in body odour over the time.

III. SWEAT GLANDS AND THEIR SECRETION

3.1 Eccrine Gland

Eccrine glands are primary sweat gland in Human body to regulate the body temperature and it is distributed throughout entire skin surface area. Eccrine glands main work is to regulate body temperature by sweat evaporation and to maintain body temperature it also releases antimicrobial peptides like Dermcidin, Cathelicidin and lactoferrin to maintain skin immunity and regulate inflammation.

Eccrine gland's structure is divided in two parts Secretory coil and Sweat duct; Secretory duct is a main producer of sweat and secrete glycoproteins and antimicrobial substances. Sweat ducts reabsorbs some ions before sweat release on skin surface.

Eccrine gland is originated by the embryonic ectoderm; Eccrine gland's sweat secretion mechanism works by controlled mainly by the sympathetic nervous system using acetylcholine. Acetylcholine binds to the muscarinic receptor on sweat gland cells and it triggers increase in intracellular Ca^{+2} and activation of ion channels and transporters.

Eccrine glands clinically play a crucial role by controlling and producing sweat and it's regulating its composition.

3.2 Apocrine Gland

Apocrine glands are exocrine sweat glands that produce thick and oily sweat. Unlike eccrine glands which regulate body temperature, it is mainly

depended on emotional sweating and certain body functions,

Apocrine glands are mainly located at armpit, ceruminous glands in ear, moll's outer edges of lips and Pelvic region.

Apocrine gland's structure is same as eccrine gland with two compartment is secretory coil which produces the secretion and another one is Sweat duct which transport the secretion into nearby hair follicle, apocrine gland is differs by eccrine gland is it's empty into hair follicle not on skin.

Apocrine glands are present at birthtime but inactive in childhood it activates and being functional at puberty due to hormonal changes.

3.3. Apoeccrine and Sebaceous Glands

Apoeccrine glands are mainly found in axilla part of 30-60% of adults in Human-being, it's secretion procedure is featured with abilily of Eccrine gland and apocrine glands, it seems to contribute almost sweat volume in axilla. Sebaceous gland is different from apocrine gland it does not secrete directly into the axillary odour itself, it secretes sebum and a mixture of lipid compounds which work as a nutrient medium to promote growth of lipophilic bacteria.

IV. BIOCHEMICAL PATHWAYS OF ODOUR PRODUCTION

4.1 The Thioalcohol pathways

Thioalcohols play a major and crucial role in production of the human body odour; Thioalcohol is a main biochemical pathway responsible for producing the characteristic strong human underarm. It is produced by breaking of C-S Bond in sweat compound and it forms a 3-Methyl 3-Sulphanylhexane-1-ol (3M3SH). 3M3SH is extremely potent compound its odour detection threshold is as low as 0.1 mole/L. It can be detected or can be smelled by even when tiny amount is present. Its sensitivity can be detected by 1 nanomole (1 billionth part of a mole), 3M3SH need very few bacterial activities is needed to produce noticeable body odour.

It is typically smells like Combined notes like Sulphurous, onion like, Topical Fruity makes familiar Human body sweat odour.

4.2 The Fatty Acid Pathway

Fatty acids are second major biochemical pathways responsible for the cause of human body odour. It is mainly associated with the corynebacterial species which Converts odourless compounds into foul smelling fatty acids. Basically, Apocrine sweat contains odourless precursor molecules, such as N- α -(3-methyl-2-hexenoyl)-L-glutamine (3M2H-Gln). Corynebacterium bacteria produce aminoacylases and glutaminases enzymes. This enzyme breaks down the precursor molecule. Which releases 3-Methyl-22-hexenoic acid (3M2H) which is volatile branched fatty acid it evaporates easily and causes foul smelling sweat.

4.3 Steroid Conversation Pathways

Apocrine gland initially secretes odorless sweat which is contains steroids like Androst-5ene-3 β -ol (androstanol) and Androsta-4-ene-3,17-dione (androstenedione). There steroids get metabolised by corynebacterium bacteria, during metabolism, oxidation and reduction reactions convert them into Androsterone (5 α -androst-16en-3-on) and Androstanol which produces characteristic odor like musky, like urine, like woody odor of axillary sweat. This compound may act as pheromone like signalling molecules but it's not confirmed yet. The Body odor is influenced by androgen (sex hormone) levels, genetic factors also affect the intensity of body odor.

4.4 Other Odour Contributing Pathways

Body Odor also get influenced by factors like age due to the changes of skin chemistry, Older adults produce higher amount of 2-nonenal which is responsible for odd unpleasant body odor, 2-Nonenal is formed by greasy and waxy Omega-7-Fatty acids like Palmitoleic Acid and Vaccenic Acid, Food Derived compound also excreted in sweat compounds so Diet is also influence the sweat composition.

V. KEY ODOUR PRODUCING MICROORGANISM

5.1 Corynebacterium Bacteria

Corynebacterium Bacteria is major odor producing microorganism for underarm malodour. These are gram positive, lipophilic and can grow in the presence or absence of oxygen. Corynebacterium Bacteria produces enzymes such as Aminoacylate which

releases 3-Methyl-2-hexenoic acid and C-S lyase which produces volatile thioalcohols produces strong sulfur/onion like odors

5.2 Staphylococcus spp.

Different staphylococcus species contributes differently to body odor like staphylococcus epidermidis produces very little unpleasant odor and helps to maintain a pleasant skin microbiome. Staphylococcus haemolyticus produces high level of C-S lyase and also generates volatile thioalcohols, leading to strong malodor.

5.3 Anaerococcus tetradius and Peptoniphilus spp.

These all bacteria are anaerobic bacteria which grow without oxygen lives deep inside hair follicles. These produce fatty acid like Butyric Acid and propanoic acid. This compound contributes overall body odor it considers a potential target for future body odor control strategies.

VI. COSMETIC AND HYGIENE APPROACH FOR ODOUR PREVENTION

6.1 Aluminium Based Antiperspirants

Aluminium Compounds are the most effective compounds for controlling underarm sweat and body odor. Common Aluminium salts are including Aluminium Chlorohydrate, Aluminium zirconium tetrachlorohydrate, glycine, Aluminium Chloride, it works by forming aluminium hydroxide plugs inside the eccrine sweat ducts. The plugs partially block sweat secretion, and reduces sweat production up to 20-35% with regular uses. Aluminium salts also create a slightly acidic environment, which slows the growth of microorganisms.

Usage of aluminium based antiperspirant concerns may cause Breast cancer or Alzheimer's disease. However, Scientific Studies and Systematic reviews haven't found any evidence of cause-and-effect relationship. Major organizations like American Cancer Society and European Food Safety Association considers these are safe to use with recommended concentrations.

6.2 Conventional Deodorants and Antimicrobial Agents

Deodorant does not stop production of body sweat it just help to prevent body odor by masking odor with

fragrances, it also kills or inhibit odor causing bacteria and neutralizes volatile odor compound which are responsible for body odor.

Common antimicrobial deodorants composed with Ethanol, Benzalkonium chloride, chlorohexidine and Triclosan. These ingredients have bacteriostatic or bactericidal effects, it reduces the number of odors causing bacteria on the underarm skin thereby reducing body odor.

6.3 Enzyme Inhibitors and Odour Precursor Interceptors

Enzymatic inhibitors are targeted to controlling body odor and also it is advanced approach to prevent body odor, it blocks the bacterial enzymes which are responsible to producing odor instead of killing the bacteria. This prevents formation of odor causing bacteria while preserving the normal skin microbiomes. Enzyme Inhibitor mainly targets C-S lyase and Aminoacylase which produces thioalcohols and 3-Methyl-2-hexenoic Acid. There are some examples of some common Enzyme Inhibitors known as Zinc ricinoleate and Plant polyphenols such as Tannic Acid Ellagic Acid and Epigallocatechin gallate (EGCG).

6.5 Natural and Plant Derived Antimicrobials

Many plant derived compounds are selectively able to kill odor causing bacteria without affecting skin friendly bacteria these natural ingredients are used as alternative to synthetic antimicrobials.

Essential oils are also effective against staphylococcus species like. Thymol, Eugenol, Carvacrol and Terpinen-4-ol these all reduce growth of odor causing bacteria at normal concentration using in cosmetic products

Techniques like Encapsulation can enhance the efficiency of plant derived antimicrobials and allows controlled and sustained release.

6.6 Emerging Technologies

In Body Odor Control we can engage technologies like Bacteriocin based Formulation, Phage Therapies and Photoactive material technologies.

Bacteriocin Based Formulations basically work on inhibiting or killing of odor causing bacteria but it is not harming any skin friendly bacteria this advantage makes it promising alternative to broad-spectrum antimicrobials.

Phage therapy is a reaction of infecting the bacteria through bacterio-phage virus. It targets bacteria such as *Corynebacterium xerosis* and Odor producing *Staphylococcus* species, it is highly specific and does not affect beneficial bacteria.

Photoactive materials can be incorporate into textiles like Clothing, which when exposed to light, they trigger a photocatalytic reaction that breakdown the volatile organic compounds responsible for body odor.

VII. INDIVIDUAL VARIATION AND INFLUENCING FACTORS

7.1 Genetic Determinants

Body Odor can be influenced person to person by genetic difference it affects production of body odor and its intensity of unpleasant smell. The most related gene to body odor is ATP-binding Cassette (ABCC11) it is expressed in apocrine glands. Mainly single nucleotide polymorphism determines how much odor precursor is secreted into sweat. Not every gene affect body odor and its formation but it influences how people smell by body odor. These includes olfactory receptor genes which detects compounds such as Androsterone, androstanol and Fatty acid. Effectiveness of gene on body odor can also influenced by environmental factors and also influences hoe individuals recognize and respond to different body odor.

7.2 Sex, Age, and Hormonal Influences

Gender difference influences quantitative and qualitative difference in formation of body odor compounds. Men's Sweat glands generally produce higher number of thioalcohols and androgenic steroids in sweat compound Whereas, the female body sweat glands produces higher amount of trans-3-Methyl-2-hexenoic Acid and more related fatty acids therefore female body odor tends to have a more sour or acidic smell. In Women Hormonal influence begins at puberty, when apocrine glands become active, female body odor changes with hormonal fluctuations during menstrual cycle, pregnancy and menopause.

According to age body odor begins at puberty and after about 40 years of age production of 2-nonenal increases which is greasy and waxy odor and is mainly responsible for the characteristic "elderly odor".

VIII. RESEARCH GAPS AND FUTURE DIRECTIONS

The extent of our understanding of how skin microbes affect body odour has not fully resolved the significant gaps. It is still unclear what enzymes are involved in the digestion of sweat components by odour-producing bacteria. Despite the effectiveness of metagenomic studies in identifying candidate genes, the confirmation of the functions of new lyases, lipase, and dehydrogenase has not kept up with practical applications. Identifying the activation and production of genes and metabolites in real-life skin conditions through a combination of metatranscriptomics, METMETMODIO, and METRIDISC could help bridge this gap.

The effects of long-term use of antiperspirants or deodorants are not easily understood. Studies presently focus on the aftermath of discontinuation, with a focus not on long-term microbial rebound but on cumulative effects on skin barrier and overall health. The absence of a well-designed, long term clinical trial to address this question is evident.

Topical probiotic cosmetics have a similar situation where they provide promising early results from small studies or laboratory tests, but lack the rigorous and reliable evidence to confirm their safety or effectiveness for daily use.

Depending on an individual's microbiome and genetic makeup (such as their ABCC11 status), there is also the potential for tailoring odour-control products to their biology. However, this remains largely a theory rather than an actuality. This would demand the use of inexpensive and dependable tools that can efficiently profile an individual's skin microbiome, as well as smart algorithms that could convert this profile into an actual odour prediction tool for product selection.

Combining techniques such as handloom fabrics, targeted cosmetics, and microbiological products could yield unique outcomes that none of these methods can achieve alone.

IX. CONCLUSION

A multifactorial biological process that causes odour is primarily caused by the interaction between odorless sweat secretions and specific microorganisms in our skin, particularly at its base. Microorganisms such as *Corynebacterium* and *Staphylococcus* turn sweat

pretensions into volatiles such as thioalcohols, short-chain fatty acids, and steroids that give off an innate body aroma.

The strength and makeup of body odour are determined by age, genetic factors, hormonal state, diet-related factors such as gender, hygiene practices, and environmental conditions.

Despite their ability to inhibit bacterial growth or sweat production, conventional deodorants and antiperspirants may have a detrimental effect on the healthy skin microbiome. Other newer approaches to odour control include enzyme inhibitors, plant-based antimicrobial and probiotics that target bacteria or viruses, as well as bacteriocins (which prevent the growth of bacteria), mycobacteria inhibitedin-1, phage therapy, and formulations targeting the microbiome.

Despite the fact that we have become more knowledgeable about the microbial and biochemical mechanisms behind body odour, there is still much research to be conducted on the functioning of specific bacterial enzymes, the impact of cosmetic products on skin microbiomes, and the development of customized odor-reducing techniques. Combined with future research in microbiome science, molecular biology, and cosmetic technology, it is anticipated that the use of these technologies will result in safer, more effective, personalized products that can prevent body unpleasantness.

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