

RESEARCH PAPER

Design and Analytical Evaluation of an Enhanced Sebumeter for Quantitative Skin Lipid Assessment

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ABSTRACT

Objectives: This study was aimed to develop and preliminarily evaluate the enhanced Sebumeter for objective assessment of skin surface lipids. The developed device was designed to detect lipid deposition on a lipid-sensitive film and convert resulting optical responses into an instrument-generated Estimated Oil Index (EOI) and interpreting the skin surface oil category. **Methods:** A mobile Sebumeter prototype was engineered using a lipid-sensitive film, TCS3200 colour sensor, ESP32 microcontroller, and OLED display. The device operated based on the optical response produced by lipid accumulation on the sampling film. A baseline reading was recorded before sample analysis. Sebum samples were collected from the right cheek of 12 individuals using lipid-sensitive films kept in contact with the skin for 5 min. Following sampling, the films were analyzed by the developed device, and the resultant EOI values were recorded.

Key findings: The developed prototype device successfully detected optical changes related with lipid deposition on sampling film and generated EOI values and category. The EOI obtained from the 12 samples ranged from 12% to 75%. The lowest EOI was observed for Sample 2 (12%), while the highest was Sample 11 (75%). Four samples were classified as dry, five as combination, and three as oily according to the differentiation used in the study. The mean EOI was 34.58%, with a median of 31.5%, indicating variation in skin surface lipid responses among participants. **Conclusion:** The developed Sebumeter device demonstrated the feasibility of utilizing a colour-sensing approach for preliminary estimation of skin surface lipids. The combination of lipid-sensitive film, TCS3200 sensor, ESP32 microcontroller, and OLED display resulted a compact and digitally integrated measurement system. However, further calibration and analytical and clinical validation using larger sample populations and established reference methods are needed before determining its quantitative equivalence with conventional Sebumeter devices.

KEYWORDS: Sebumeter, Skin surface lipids, Lipid-sensitive film, TCS3200 colour sensor, ESP32, Estimated Oil Index, Skin type.

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INTRODUCTION

Human skin is mostly divided into three types i.e. dry, oily, or combination/moderate, as per the secretion of sebum. Human skin possesses sebaceous glands all over the body surface except the palms and soles. Influenced sebum secretion activity was seen due to the sex hormone androgens, especially during puberty. Skin appears shiny because of overabundant secreted sebum, becoming a vital factor for acne development. Age, sex, genetics, and anatomical location can influence sebum production. The naturally occurring sebum of skin surface shows a 4.2 to 5.6 pH range¹⁻³.

Measuring the skin oil is important for the selection of suitable cosmetic and skincare products. Optimum sebum levels protect skin by preventing water loss and microbial growth, and they influence the permeation of pharmaceutical and cosmetic substances. Sebaceous glands are classified as holocrine glands and are present in the dermis region. Sebum production and release was done by sebocytes. Triglycerides, free fatty acids, wax esters, squalene and cholesterol combines to form the sebum. Abnormal sebum levels can be prone to acne, seborrheic dermatitis and oily skin⁵.

Sebum analysis market is very vast, containing aluminium foil method, cotton swab method, sebutape method, etc. One of the important method is grease spot photometry (Sebumeter[®]) measures total skin-lipid but unable to identify individual components or give absolute quantification⁷. GC-MS is also utilized for skin-lipid analysis but unsuitable for non-volatile lipids. MALDI-MS has limitations in identifying lower molecular weight lipids⁸. ESI-MS provides sensitive and specific analysis of multiple sebum-lipids and also suitable for lipidomic studies, but salt interference, ion suppression, carryover and instrument variation can affects the results⁹. Since subjective assessment of skin type may differ from actual sebum levels, objective measurement is important. The study therefore used a non-invasive Sebumeter method to assess regional sebum secretion, determine skin type.

MATERIALS and METHODS

Design of Sebumeter

The Sebumeter was designed on the principle that accumulation of lipid content on a translucent sampling material alters its optical transmission. The device displays change in optical transmission into a numerical signal proportional to the quantity of lipid accumulated to the

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sampling surface. period of 5 min.

The proposed design consists of:

- ESP32 microprocessor
- TCS3200 color sensor
- PC OLED display
- 18650 Li-ion cell
- 18650 battery holder
- TP4056 charging/protection module
- Connecting wires

Controlled-Pressure Sampling

Operator-applied pressure can be variable, greater pressure may increase lipid transfer from the skin to the lipid sensitive plastic strip. The device therefore uses a spring-loaded sampling head designed to maintain a predefined contact force. The applied pressure should be optimum during development and during sampling procedure for a predefined

Optical Measurement System

The optical system consisted of an LED light source and photodiode detector positioned on opposite sides of the sampling material. The detector measures transmitted light intensity after lipid deposition.

Mechanism of sebum estimation by sebumeter

The sebumeter works on grease-spot photometry principle. The measuring head of the cassette with sample containing lipid sensitive tape is placed on the skin. It is then placed into the slot of device, where the transparency is measured by a light source passing through the lipid sensitive tape. A photodiode detector measures the transparency. The ESP32 microprocessor calculates the result, which is shown on the display in % and interprets the skin as dry, oily, or combination.

Table no.1 classification of sebum level

Sr.no.	Percentage	Classification	Estimated Oil Level
1.	0-20%	Dry	Low
2.	21-40%	Normal	Moderate
3.	41-50%	Combination	Moderately high
4.	51-100%	Oily	High

Sebum Sampling

Sebum samples were collected by Dr. Priyanka Dodake (MBBS, MD Skin & VD) at PANDHARPUR SKIN CLINIC using modified procedure from Camera E et al. The participant's faces were washed using standardized cleanser. Complete removal of sebum was verified using tissue paper. The lipid sensitive films were applied for 5 min to the right cheek side of the faces. After sampling, carefully films were removed using cleaned forceps, and stored in a clean and dry container until further analysis at 2°C. Total 12 individuals participated in the sampling procedure and 12 interpretations were collected by the developed sebumeter.

RESULT

A mobile prototype sebumeter was successfully developed by using TCS3200, ESP32 microcontroller, colour sensor, and OLED display. The designed system detect produced optical changes on sebum absorbed lipid sensitive film and convert those responses into an Estimated Oil Index (EOI). The frequency responses like red, green, blue, and clear-channel was provided by the TCS3200. A baseline measurement was recorded before sample analysis to provide a reference for subsequent measurements.

The developed sebumeter was preliminarily evaluated using the lipid-sensitive films obtained from 12 individuals. Each film was pasted to the cheek region for 5 min before instrument analysis. The EOI values obtained from the developed Sebumeter varied among the tested samples, ranging from 12% to 75%, demonstrating its ability to show different levels of lipid deposition on the lipid sensitive film.

The lowest EOI was observed for Sample 2 (12%), followed

by Sample 1 (14%), Sample 3 (16%), and Sample 7 (18%). These samples were classified as having relatively low surface oil levels. Combination EOI values were obtained for Sample 6 (22%), Sample 9 (24%), Sample 10 (39%), Sample 12 (40%), as well as Sample 4 (42%). In the opposite, Samples 5, 8, and 11 exhibited higher EOI values of 51%, 62%, and 75%, respectively, and were recognized as oily. Sample 11 showed the highest recorded EOI, whereas Sample 2 exhibited the lowest value among all the samples.

DISCUSSION

The developed system displayed a direct digital output in % following sensor acquisition and processing. The measurement sequence involved acquisition of R, G, B, and clear-channel frequencies, optical processing, and conversion into an Estimated Oil Index (%). The resulting value was displayed through the OLED interface in %, along with an interpreted skin-oil category (Dry, oily, or combination). The present study focused on the development and preliminary analytical evaluation of an enhanced Sebumeter for the assessment of skin surface lipids. The proposed prototype combined a lipid-sensitive film with a TCS3200 colour sensor, ESP32 microcontroller, and OLED display to offer a simple and portable approach for estimating changes in surface lipid deposition. The prototype was designed to overcome some practical limitations associated with conventional visual assessment by converting the lipid sensitive film response into an instrument-generated Estimated Oil Index (EOI). The use of a baseline reading prior measurement provided a reference for interpreting the change produced after contact with the lipid sensitive film. Preliminary evaluation established measurable differences in EOI among the 12 participants. The recorded values ranged

from 12% to 75%, indicating considerable variation in skin surface lipid deposition between each individuals. Sample 2 produced the lowest EOI of 12%, whereas Sample 11 showed the highest value of 75%. The observed response variation suggests that the developed prototype was capable of detecting differences in the colour response of the lipid-sensitive film. The results were further grouped into dry, combination, and oily categories according to the classification adopted in the study. Four samples were classified as dry, five as combination, and three as oily. The mean EOI of the 12 observations was 34.58%, with a median of 31.5%. The relatively broad range of observed values exhibits significant inter-individual variation in the measured skin surface lipid response.

Such variation is expected when samples are obtained from uncategorized individuals and shows the importance of standardized sampling conditions when evaluating skin lipid measurement devices.

The performance of the developed prototype is particularly relevant because the device provides an electronic output rather than other methods like make dilution or analyse using high-end instruments. Integrating the TCS3200 sensor with the ESP32 microcontroller enabled colour-related sensor responses to be processed and displayed on the OLED. This approach offers the basis for a compact and potentially cost-effective instrument for preliminary skin lipid assessment. The electronic configuration also allows for future modifications, including enhanced data processing, digital storage, wireless transmission, and development of user-friendly measurement interfaces. The present findings should be taken as a preliminary evaluation rather than a complete analytical validation of the instrument. The current study therefore demonstrates the feasibility of the measurement principle rather than establishing clinical equivalence with established instruments. The smaller sample size is another important consideration. Although the 12 measurements exhibited high variation across the selected EOI categories, the dataset is inadequate to set up the general performance of the device across different populations, ages, skin types, anatomical sites. In addition, parameters such as repeatability, reproducibility, accuracy, precision, sensitivity, and calibration linearity were not fully established in the present investigation. These aspects should be managed in subsequent studies using a larger number of subjects and systematic experimental conditions.

Overall, the preliminary findings support the feasibility of utilizing a colour-sensing approach for electronic estimation of skin surface lipids. The consolidation of a lipid-sensitive film, TCS3200 sensor, ESP32 processing unit, and OLED display produced distinct EOI values across the tested samples of individuals. The study therefore provides a foundation for further development and analytical validation of the developed prototype. Future investigations should focus on calibration against established reference measurements, repeated measurements on the same subjects, assessment of inter- and intra-day variability, larger clinical datasets, and direct comparison with marketed available Sebumeter systems.

CONCLUSION

This study successfully exhibited the feasibility of

developing an enhanced Sebumeter for preliminary assessment of skin surface lipids using a lipid-sensitive film, TCS3200 colour sensor, ESP32 microcontroller, and OLED display. The developed prototype provided an instrument generated Estimated Oil Index (EOI) that made differentiation of lipid responses among the tested human skin oil samples. In the preliminary evaluation of 12 participants, EOI values ranged from 12% to 75%, proving noticeable variation in skin surface lipid deposition. Based on the classification used in the study, the samples were divided into dry, combination, and oily categories, indicating that the developed prototype device could detect the differences in surface lipid levels.

The developed device offers a compact and potentially cost-effective alternative approach for preliminary skin lipid assessment, with scope for further improvement in portability, digital processing, data storage and management. In future, analytical and clinical validation is required before establishing its equivalence with conventional Sebumeter measurements. Further studies should include calibration against validated reference methods, larger sample populations, repeated measurements, and evaluation of accuracy, precision, repeatability, and reproducibility. Overall, the study offers a promising foundation for future development of an enhanced, digitally integrated skin lipid measurement device.

REFERENCES

1. Youn, S. W., Kim, S. J., Hwang, I. A., & Park, K. C. (2002). Evaluation of facial skin type by sebum secretion: discrepancies between subjective descriptions and sebum secretion. *Skin research and technology : official journal of International Society for Bioengineering and the Skin (ISBS) [and] International Society for Digital Imaging of Skin (ISDIS) [and] International Society for Skin Imaging (ISSI)*, 8(3), 168–172. <https://doi.org/10.1034/j.1600-0846.2002.10320.x>
2. Park, S.G., Kim, Y.D., Kim, J.J. and Kang, S.H. (1999), Two possible classifications of facial skin type by two parameters in Korean women: sebum excretion rate (SER) and skin surface relief (SSR). *Skin Research and Technology*, 5: 189-194. <https://doi.org/10.1111/j.1600-0846.1999.tb00130.x>
3. Fur, I.L., Lopez, S., Morizot, F., Guinot, C. and Tschachler, E. (1999), Comparison of cheek and forehead regions by bioengineering methods in women with different self-reported “cosmetic skin types”. *Skin Research and Technology*, 5: 182-188. <https://doi.org/10.1111/j.1600-0846.1999.tb00129.x>
4. Kapoor, S. (2012). Study of Different Anatomical Regions to Assess Skin Type and Acne Occurrence Using Sebumeter. *Research Journal of Topical and Cosmetic Sciences*, 3(2), IV.
5. Sheu, H. M., Chao, S. C., Wong, T. W., Yu-Yun Lee, J., & Tsai, J. C. (1999). Human skin surface lipid film: an ultrastructural study and interaction with corneocytes and intercellular lipid lamellae of the stratum corneum. *The British journal of dermatology*, 140(3), 385–391. <https://doi.org/10.1046/j.1365-2133.1999.02697.x>

6. Pande, S. Y., & Misri, R. (2005). Sebumeter. *Indian journal of dermatology, venereology and leprology*, 71(6), 444–446. <https://doi.org/10.4103/0378-6323.18959>
7. Géhin, C., Tokarska, J., Fowler, S.J. *et al.* No skin off your back: the sampling and extraction of sebum for metabolomics. *Metabolomics* 19, 21 (2023). <https://doi.org/10.1007/s11306-023-01982-3>
8. Kendall AC, Koszyczarek MM, Jones EA, *et al.* *Lipidomics for translational skin research: A primer for the uninitiated.* *Exp Dermatol.* 2018; 27: 721–728. <https://doi.org/10.1111/exd.13558>
9. Harald C. Köfeler, Robert Ahrends, Erin S. Baker, Kim Ekroos, Xianlin Han, Nils Hoffmann, Michal Holčapek, Markus R. Wenk, Gerhard Liebisch, Recommendations for good practice in MS-based lipidomics, *Journal of Lipid Research*, Volume 62, 2021, 100138, ISSN 0022-2275, <https://doi.org/10.1016/j.jlr.2021.100138>.
10. Piérard-Franchimont, C., Piérard, G. E., Saint-Léger, D., Lévêque, J. L., & Kligman, A. M. (1991). Comparison of the kinetics of sebum secretion in young women with and without acne. *Dermatologica*, 183(2), 120–122. <https://doi.org/10.1159/000247650>.
11. Piérard, G. E., Piérard-Franchimont, C., & Lê, T. (1987). Seborrhoea in acne-prone and acne-free patients. *Dermatologica*, 175(1), 5–9. <https://doi.org/10.1159/000248774>.
12. Emanuel, S. V. (1938). Mechanism of the sebum secretion. *Acta dermat.-venereol*, 19, 1-19.
13. Youn, S. W., Kim, S. J., Hwang, I. A., & Park, K. C. (2002). Evaluation of facial skin type by sebum secretion: discrepancies between subjective descriptions and sebum secretion. *Skin Research and Technology*, 8(3), 168-172.
14. Ahn, K., Han, S., Yun, K., Lee, W., Lee, D. G., Kang, S. M., ... & Ahn, Y. J. (2022). A real-time detection device for the rapid quantification of skin casual sebum using the Oil Red O staining method. *Sensors*, 22(8), 3016.
15. Serup, J. (1991). Formation of oiliness and sebum output—comparison of a lipid-absorbant and occlusive-tape method with photometry. *Clinical and experimental dermatology*, 16(4), 258-263.
16. Banyś, A., Hartman-Petrycka, M., Kras, K., Kamińska, M., Krusiec-Świdergoł, B., Popielski, P., ... & Wilczyński, S. (2023). The influence of sebum on directional reflectance of the skin. *Applied Sciences*, 13(5), 2838.
17. Ezerskaia, A., Pereira, S. F., Urbach, H. P., & Varghese, B. (2016, May). Infrared spectroscopic measurement of skin hydration and sebum levels and comparison to corneometer and sebumeter. In *Biophotonics: Photonic Solutions for Better Health Care V* (Vol. 9887, pp. 261-266). SPIE.
18. Kim, N. Y., Kim, B. R., Jung, M. G., Park, S. H., Jin, H. Y., Jang, H. J., & Kim, S. J. (2022). Comparison analysis of tests for the sebum content on the scalp using Meibometer® and Sebumeter®. *Asian Journal of Beauty and Cosmetology*, 20(3), 315-323.
19. Saloki, A., Kukreja, T., Gaikwad, S., Kumar, A., Parker, A., Dowand, B., ... & Saraf, S. (2022). Cosmetic Testing Equipment: Device and Types of Equipment for Dermatological Evaluation for Women's Skin. *Journal of Ravishankar University*, 35(2), 19-43.
20. Furuichi, M., Makino, T., Matsunaga, K., Hamade, E., Yokoi, H., & Shimizu, T. (2010). The usefulness of sebum check film for measuring the secretion of sebum. *Archives of dermatological research*, 302(9), 657-660.
21. Bajor, J. S., Becker, W. D., Hillmer, S., & Knaggs, H. (1998). Measurement and analysis of human surface sebum levels using the sebumeter. *Journal of Dermatological Science*, 16, S215.
22. Gabard, B., Barel, A. O., & Clarys, P. (2013). Sebumetry and Sebumtape. In *Non Invasive Diagnostic Techniques in Clinical Dermatology* (pp. 269-277). Berlin, Heidelberg: Springer Berlin Heidelberg.
23. Dobrev, H. (2007). Clinical and instrumental study of the efficacy of a new sebum control cream. *Journal of cosmetic dermatology*, 6(2), 113-118.