Fig. 11 LDA plot for three quality levels of dried black tea. (a) without heating or treatment I, (b) with unstable heating or treatment II, and (c) with stable heating or treatment III

IV. CONCLUSIONS

The e-nose with highly stable and controllable sample heater system was successfully developed by applying PID controller. The sensor response exhibits significantly dependent on the temperature of the sample. Without heating treatment, the e-nose is not able to distinguish the three quality levels of black tea correctly. By applying the unstable heating treatment, the performance of the e-nose was improved significantly. When using the stable and controllable sample heater, all samples are separated clearly, where 97.8% of original grouped and 97.8% of cross-validated grouped are correctly classified.

REFERENCES

[1] N. Bhattacharyya, B. Tudu, R. Bandyopadhyay, M. Bhuyan, and R. Mudi, "Aroma characterization of orthodox black tea with electronic nose," in *TENCON 2004. 2004 IEEE Region 10 Conference*, 2004, vol. B, p. 427–430 Vol. 2.

[2] R. Banerjee, P. Chattopadhyay, R. Rani, B. Tudu, R. Bandyopadhyay, and N. Bhattacharyya, *Discrimination of black tea using electronic nose and electronic tongue: A Bayesian classifier approach*. IEEE, 2011, pp. 13–17.

[3] T. Sinha, "Discrimination of tea quality by polymer membrane electrode based potentiometric taste sensor," pp. 781–784, Dec. 2012.

[4] B. Banerjee, "Tea Production and Processing." Oxford and IBH Publ. Co. Private Limited, New Delhi, India, p. 2, 1993.

[5] M. Ghasemi-Varnamkhasti, S. S. Mohtasebi, M. L. Rodriguez-Mendez, J. Lozano, S. H. Razavi, and H. Ahmadi, "Potential application of electronic nose technology in brewery," *Trends Food Sci. Technol.*, vol. 22, no. 4, pp. 165–174, 2011.

[6] Z. Zhao, F. Tian, H. Liao, X. Yin, Y. Liu, and B. Yu, "Sensors and Actuators B : Chemical A novel spectrum analysis technique for odor-sensing in the optical electronic nose," *Sensors Actuators B. Chem.*, vol. 222, pp. 769–779, 2016.

[7] K. Yan and D. Zhang, "Calibration transfer and drift compensation of e-noses via coupled task learning," *Sensors Actuators B Chem.*, vol. 225, pp. 288–297, 2016.

[8] D. Ha, Q. Sun, K. Su, H. Wan, H. Li, N. Xu, F. Sun, L. Zhuang, N. Hu, and P. Wang, "Recent achievements in electronic tongue and bioelectronic tongue as taste sensors," *Sensors Actuators B Chem.*, vol. 207, pp. 1136–1146, 2015.

[9] S. Qiu, J. Wang, and L. Gao, "Qualification and quantisation of processed strawberry juice based on electronic nose and tongue," *LWT - Food Sci. Technol.*, vol. 60, no. 1, pp. 115–123, 2015.

[10] L. Lvova, R. Pudi, P. Galloni, V. Lippolis, C. Di Natale, I. Lundström, and R. Paolesse, "Multi-transduction sensing films for Electronic Tongue applications," *Sensors Actuators B Chem.*, vol. 207, pp. 1076–1086, 2015.

[11] B. Tudu, A. Jana, A. Metla, D. Ghosh, N. Bhattacharyya, and R. Bandyopadhyay, "Electronic nose for black tea quality evaluation by an incremental RBF network," *Sensors Actuators, B Chem.*, vol. 138, no. 1, pp. 90–95, 2009.

[12] H. Nanto and J. R. Stetter, "Introduction to Chemosensors," in *Handbook of Machine Olfaction*, Wiley-VCH Verlag GmbH & Co. KGaA, 2004, pp. 79–104.

[13] W. Yan, Z. Tang, G. Wei, J. Yang, L. Province, and S. Province, "An Electronic Nose Recognition Algorithm Based on PCA-ICA Preprocessing and Fuzzy Neural Network," pp. 1227–1230, 2012.

[14] Figaro, "PRODUCT INFORMATION TGS 2600 - for the detection of Air Contaminants," 2001.

[15] D. Lelono, K. Triyana, S. Hartati, and J. E. Istiyanto, "principal component analysis Classification of Indonesia Black Teas Based on Quality by Using Electronic Nose and Principal Component Analysis," in *AIP Conference Proceedings*, 2016, vol. 1755, pp. 20003–1.

[16] J. Yan, X. Guo, S. Duan, P. Jia, L. Wang, C. Peng, and S. Zhang, "Electronic Nose Feature Extraction Methods: A Review," *Sensors*, vol. 15, pp. 27804–27831, 2015.