Chapter

2

MOLECULAR TECHNIQUES IN STRAWBERRY

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THE STRAWBERRY FRUIT

Strawberry is among the fruits that are grown in very wide ecological conditions and the production is increasing day by day. Recently, there are many studies on health-related to strawberry fruit and they have reported that strawberry fruits are known to be very beneficial for health with the content of mineral substances, folic acid, vitamin C and phenolic compounds providing a high amount of natural antioxidants to consumers. Besides, detailed analysis has shown that consumption of strawberries allows getting fat-soluble vitamins and carotenoids such as vitamin A and E. This fragrant and flavored fruit, providing the energy of 32 kcal from about 100 grams, which may be a great option food against obesity, which is the most important problem of recent years. It is reported that the antioxidant content of strawberries is significantly related to the strawberry species and variety (Giampieri et al, 2013; Sarıdaş, 2019; Sarıdaş et al, 2020). In light of this information, the consumption of strawberry fruits with high antioxidant content is of critical importance for health. The development of new strawberry varieties rich in content with other quality criteria such as yield, size, color, etc. is one of the most significant and priority issues of today's time. Besides being a healthy food with low calories, strawberry fruits are a good alternative to processed products due to their sweet aroma. Also, some strawberry varieties were found to contain higher levels of vitamin C than citrus fruits. Among edible foods; It was determined that

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REFERENCES

1. Al-Khayri, J. M. & Islam, R. (2018). Genetic Improvement of Strawberry (Fragaria× ananassa Duchesne). In *Advances in Plant Breeding Strategies: Fruits,* 217-275. Springer, Cham.
2. Badakhshan, H., Kamangar, M. S. & Mozafari, A. A. (2018). Characterization of strawberry (Fragaria× ananassa Duch.) cultivars using SCoT, ISSR and IRAP markers. *Crop Breeding Journal*, *8* (2), 61-72.
3. Bassil, N. V., Gunn, M., Folta, K. & Lewers, K. (2006a). Microsatellite markers for Fragaria from 'Strawberry Festival'expressed sequence tags. *Molecular Ecology Notes*, *6* (2), 473-476.
4. Bassil, N. V., Njuguna, W. & Slovin, J. P. (2006b). EST-SSR markers from Fragaria vesca L. cv. Yellow Wonder. *Molecular Ecology Notes*, *6* (3), 806-809.
5. Biswas, A., Melmaiee, K., Elavarthi, S., Jones, J. & Reddy, U. (2019). Characterization of strawberry (Fragaria spp.) accessions by genotyping with SSR markers and phenotyping by leaf antioxidant and trichome analysis. *Scientia Horticulturae*, *256*, 108561.
6. Castro, P., Bushakra, J. M., Stewart, P., Weebadde, C. K., Wang, D., Hancock, J. F., ... & Lewers, K. S. (2015). Genetic mapping of day-neutrality in cultivated strawberry. *Molecular breeding*, *35* (2), 79.
7. Chambers, A., Carle, S., Njuguna, W., Chamala, S., Bassil, N., Whitaker, V. M., ... & Folta, K. M. (2013). A genome-enabled, high-throughput, and multiplexed fingerprinting platform for strawberry (Fragaria L.). *Molecular breeding*, *31* (3), 615-629.
8. Chen, P., Wang, Y. Z., Liu, Q. Z., Li, W. H., Li, H. Q., Li, X. Y. & Zhang, Y. T. (2020). Transcriptomic analysis reveals recovery strategies in strawberry roots after using a soil amendment in continuous cropping soil. *BMC Plant Biology*, *20* (1), 1-11.
9. Cipriani, G., Lot, G., Huang, W. G., Marrazzo, M. T., Peterlunger, E. & Testolin, R. (1999). AC/GT and AG/CT microsatellite repeats in peach [Prunus persica (L) Batsch]: isolation, characterisation and cross-species amplification in Prunus. *Theoretical and Applied Genetics*, *99* (1-2), 65-72.
10. Davis, T. M. (2015). *Geographical distribution of strawberries*. University of New Hampshire New Hampshire Agricultural Experiment Station, Durham, NH. http://strawberrygenes.unh.edu/map.html
11. Degani, C., Rowland, L. J., Levi, A., Hortynski, J. A. & Galletta, G. J. (1998). DNA fingerprinting of strawberry (Fragaria× ananassa) cultivars using randomly amplified polymorphic DNA (RAPD) markers. *Euphytica*, *102* (2), 247-253.
12. Dönmez, D., Şimşek, Ö. & Kaçar, Y. A. (2015). Yeni nesil DNA dizileme teknolojileri ve bitkilerde kullanımı. *Türk Bilimsel Derlemeler Dergisi*, *8* (1), 30-37.
13. Dönmez, D., Şimşek, Ö. & Kaçar, Y. A. (2016). Genetic engineering techniques in fruit science. *Int J Environ Agr Res*, *2* (12), 115-128.
14. Edger, P. P., Poorten, T. J., VanBuren, R., Hardigan, M. A., Colle, M., McKain, M. R., ... & Alger, E. I. (2019). Origin and evolution of the octoploid strawberry genome. *Nature genetics*, *51* (3), 541-547.
15. Edger, P. P., VanBuren, R., Colle, M., Poorten, T. J., Wai, C. M., Niederhuth, C. E., ... & Callow, P. (2018). Single-molecule sequencing and optical mapping yields an improved genome of woodland strawberry (Fragaria vesca) with chromosome-scale contiguity. *Gigascience*, *7* (2), gix124.
16. Fritzmann, C., Xuan, H. & Schilling, K. (2012). A Microsatellite (SSR)-Based Genetic Method to Identify Strawberry (Fragaria× ananassa) Cultivars. In *VII International Strawberry Symposium 1049*, 359-364.
17. Garcia, M. G., Ontivero, M., Diaz Ricci, J. C. & Castagnaro, A. (2002). Morphological traits and high resolution RAPD markers for the identification of the main strawberry varieties cultivated in Argentina. *Plant Breeding*, *121* (1), 76-80.
18. Ge, A., Shangguan, L., Zhang, X., Dong, Q., Han, J., Liu, H., ... & Fang, J. (2013). Deep sequencing discovery of novel and conserved microRNAs in strawberry (Fragaria× ananassa). *Physiologia plantarum*, *148* (3), 387-396.

19. Giampieri, F., Alvarez-Suarez, J. M., Mazzoni, L., Romandini, S., Bompadre, S., Diamanti, J., ... & Tulipani, S. (2013). The potential impact of strawberry on human health. *Natural product research*, *27* (4-5), 448-455.
20. Gil-Ariza, D. J., Amaya, I., Botella, M. A., Blanco, J. M., Caballero, J. L., López-Aranda, J. M., ... & Sánchez-Sevilla, J. F. (2006). EST-derived polymorphic microsatellites from cultivated strawberry (Fragaria× ananassa) are useful for diversity studies and varietal identification among Fragaria species. *Molecular Ecology Notes*, *6* (4), 1195-1197.
21. Goldberg, M. T., Spigler, R. B. & Ashman, T. L. (2010). Comparative genetic mapping points to different sex chromosomes in sibling species of wild strawberry (Fragaria). *Genetics*, *186* (4), 1425-1433.
22. Goulão, L., Monte-Corvo, L. & Oliveira, C. M. (2001). Phenetic characterization of plum cultivars by high multiplex ratio markers: Amplified fragment length polymorphisms and inter-simple sequence repeats. *Journal of the American Society for Horticultural Science*, *126* (1), 72-77.
23. Govan, C. L., Simpson, D. W., Johnson, A. W., Tobutt, K. R. & Sargent, D. J. (2008). A reliable multiplexed microsatellite set for genotyping Fragaria and its use in a survey of 60 F.× ananassa cultivars. *Molecular Breeding*, *22* (4), 649-661.
24. Gülşen, O., Mutlu, N. (2005). Bitki biliminde kullanılan genetik markırlar ve kullanım alanları. *Alatarım*, 4(2), 27-37, (In Turkish).
25. Hadonou, A. M., Sargent, D. J., Wilson, F., James, C. M. & Simpson, D. W. (2004). Development of microsatellite markers in Fragaria, their use in genetic diversity analysis, and their potential for genetic linkage mapping. *Genome*, *47* (3), 429-438.
26. Hadonou, M., Sargent, D., Walden, R. & Simpson, D. (2003). Characterisation of Fragaria vesca single sequence repeats (SSR) markers. In *Euro Berry Symposium-COST-Action 836 Final Workshop 649*, 99-102.
27. Hancock, J. F., Sjulin, T. M. & Lobos, G. A. (2008). Strawberries. In *Temperate fruit crop breeding*, 393-437. Springer, Dordrecht.
28. Hirakawa, H., Shirasawa, K., Kosugi, S., Tashiro, K., Nakayama, S., Yamada, M., ... & Tsuruoka, H. (2014). Dissection of the octoploid strawberry genome by deep sequencing of the genomes of Fragaria species. *DNA research*, *21* (2), 169-181.
29. Hokanson, K. E., Smith, M. J., Connor, A. M., Luby, J. J. & Hancock, J. F. (2006). Relationships among subspecies of New World octoploid strawberry species, Fragaria virginiana and Fragaria chiloensis, based on simple sequence repeat marker analysis. *Botany*, *84* (12), 1829-1841.
30. Honjo, M., Nunome, T., Kataoka, S., Yano, T., Yamazaki, H., Hamano, M., ... & Morishita, M. (2011). Strawberry cultivar identification based on hypervariable SSR markers. *Breeding science*, *61* (4), 420-425.
31. Hossain, M. R., Natarajan, S., Kim, H. T., Jesse, D. M. I., Lee, C. G., Park, J. I. & Nou, I. S. (2019). High density linkage map construction and QTL mapping for runner production in allo-octoploid strawberry Fragaria× ananassa based on ddRAD-seq derived SNPs. *Scientific reports*, *9* (1), 1-11.
32. Kang, C., Li, Y., Feng, J., Cheng, L., Dai, C. & Liu, Z. (2019). Gene expression profiling of the shoot meristematic tissues in woodland strawberry Fragaria vesca. *Frontiers in Plant Science*, *10*, 1624.
33. Kim, J., Lee, S. Y., Kim, D., Lee, E. S., Lee, H. E., Han, K. & Kang, B. C. (2019). Genotyping of octoploid strawberry inbred lines by SNP discovery using genotyping-by-sequencing. *Horticulture, Environment, and Biotechnology*, *60* (1), 69-80.
34. Kumari, S., Sharma, S. K. & Kumar, A. (2019). Molecular Characterization of Different Strawberry (Fragaria x ananassa Duch.) Cultivars Growing under Mid Hill Conditions of Himachal Pradesh. *International Journal of Agriculture, Environment and Biotechnology*, *12* (4), 331-337.
35. Le Nguyen, K., Grondin, A., Courtois, B. & Gantet, P. (2019). Next-generation sequencing accelerates crop gene discovery. *Trends in plant science*, *24* (3), 263-274.

36. Lerceteau-Köhler, E., Guerin, G., Laigret, F. & Denoyes-Rothan, B. (2003). Characterization of mixed disomic and polysomic inheritance in the octoploid strawberry (Fragaria× ananassa) using AFLP mapping. *Theoretical and Applied Genetics*, *107* (4), 619-628.
37. Lewers, K. S., Styan, S. M. N., Hokanson, S. C. & Bassil, N. V. (2005). Strawberry GenBank-derived and genomic simple sequence repeat (SSR) markers and their utility with strawberry, blackberry, and red and black raspberry. *Journal of the American Society for Horticultural Science*, *130* (1), 102-115.
38. Li, Y., Dai, C., Hu, C., Liu, Z. & Kang, C. (2017). Global identification of alternative splicing via comparative analysis of SMRT-and Illumina-based RNA-seq in strawberry. *The Plant Journal*, *90* (1), 164-176.
39. Li, Y., Wei, W., Feng, J., Luo, H., Pi, M., Liu, Z. & Kang, C. (2018). Genome re-annotation of the wild strawberry Fragaria vesca using extensive Illumina-and SMRT-based RNA-seq datasets. *DNA Research*, *25* (1), 61-70.
40. Meng, F., Liu, L., Peng, M., Wang, Z., Wang, C. & Zhao, Y. (2015). Genetic diversity and population structure analysis in wild strawberry (Fragaria nubicola L.) from Motuo in Tibet Plateau based on simple sequence repeats (SSRs). *Biochemical Systematics and Ecology*, *63*, 113-118.
41. Monfort, A., Vilanova, S., Davis, T. M. & Arús, P. (2006). A new set of polymorphic simple sequence repeat (SSR) markers from a wild strawberry (Fragaria vesca) are transferable to other diploid Fragaria species and to Fragaria× ananassa. *Molecular Ecology Notes*, *6* (1), 197-200.
42. Pincot, D. D., Poorten, T. J., Hardigan, M. A., Harshman, J. M., Acharya, C. B., Cole, G. S., ... & Knapp, S. J. (2018). Genome-wide association mapping uncovers Fw1, a dominant gene conferring resistance to Fusarium wilt in strawberry. *G3: Genes, Genomes, Genetics*, *8* (5), 1817-1828.
43. Powell, W., Morgante, M., Andre, C., Hanafey, M., Vogel, J., Tingey, S. & Rafalski, A. (1996). The comparison of RFLP, RAPD, AFLP and SSR (microsatellite) markers for germplasm analysis. *Molecular breeding*, *2* (3), 225-238.
44. Rousseau-Gueutin, M., Lerceteau-Köhler, E., Barrot, L., Sargent, D. J., Monfort, A., Simpson, D., ... & Denoyes-Rothan, B. (2008). Comparative genetic mapping between octoploid and diploid Fragaria species reveals a high level of colinearity between their genomes and the essentially disomic behavior of the cultivated octoploid strawberry. *Genetics*, *179* (4), 2045-2060.
45. Rugienius, R., Šikšnianienė, J. B., Frercks, B., Stanienė, G., Stepulaitienė, I., Haimi, P. & Stanys, V. (2015). Characterization of strawberry (Fragaria× ananassa Duch.) cultivars and hybrid clones using SSR and AFLP markers. *Zemdirbyste-Agriculture*, *102* (2).
46. Samad, S., Kurokura, T., Koskela, E., Toivainen, T., Patel, V., Mouhu, K., ... & Hytönen, T. (2017). Additive QTLs on three chromosomes control flowering time in woodland strawberry (Fragaria vesca L.). *Horticulture research*, *4* (1), 1-11.
47. Sánchez-Sevilla, J. F., Horvath, A., Botella, M. A., Gaston, A., Folta, K., Kilian, A., ... & Amaya, I. (2015). Diversity Arrays Technology (DArT) marker platforms for diversity analysis and linkage mapping in a complex crop, the octoploid cultivated strawberry (Fragaria× ananassa). *PLoS One*, *10* (12).
48. Sánchez-Sevilla, J. F., Vallarino, J. G., Osorio, S., Bombarely, A., Posé, D., Merchante, C., ... & Valpuesta, V. (2017). Gene expression atlas of fruit ripening and transcriptome assembly from RNA-seq data in octoploid strawberry (Fragaria× ananassa). *Scientific reports*, *7* (1), 1-13.
49. Sargent, D. J., Fernandéz-Fernandéz, F., Ruiz-Roja, J. J., Sutherland, B. G., Passey, A., Whitehouse, A. B. & Simpson, D. W. (2009). A genetic linkage map of the cultivated strawberry (Fragaria× ananassa) and its comparison to the diploid Fragaria reference map. *Molecular Breeding*, *24* (3), 293-303.
50. Sargent, D. J., Hadonou, A. M. & Simpson, D. W. (2003). Development and characterization of polymorphic microsatellite markers from Fragaria viridis, a wild diploid strawberry. *Molecular Ecology Notes*, *3* (4), 550-552.
51. Saridas, M.A., Simsek, O., Donmez, D., Aka Kacar, Y., PAydas Kargi, S. (2020). Genetic diversity and fruit characteristics of new superior hybrid strawberry (Fragaria × ananassa Duchesne ex Rozier) genotypes. *Genetic Resources and Crop Evolution*, https://doi.org/10.1007/s10722-020-01020-4

52. Sarıdaş, M. A. (2018). Melezleme ıslahıyla seçilmiş çilek genotiplerinin verim, kalite özelliklerinin belirlenmesi ve moleküler karakterizasyonu (Doktora Tezi). *Çukurova Üniversitesi Fen Bilimleri Enstitüsü*, 338.
53. Scalzo, J., Politi, A., Pellegrini, N., Mezzetti, B. & Battino, M. (2005). Plant genotype affects total antioxidant capacity and phenolic contents in fruit. *Nutrition*, *21* (2), 207-213.
54. Semagn, K., Bjørnstad, Å. & Ndjiondjop, M. N. (2006). Principles, requirements and prospects of genetic mapping in plants. *African Journal of Biotechnology*, *5* (25).
55. Shulaev, V., Sargent, D. J., Crowhurst, R. N., Mockler, T. C., Folkerts, O., Delcher, A. L., ... & Burns, P. (2011). The genome of woodland strawberry (Fragaria vesca). *Nature genetics*, *43* (2), 109.
56. Simsek, O., Donmez, D. & Kacar, Y. A. (2017). RNA-Seq analysis in fruit science: a review. *Am. J. Plant Biol*, *2* (5), 1.
57. Şimşek, Ö., Dönmez, D., Eti, S., Yeşiloğlu, T. & Kaçar, Y. (2019). Comparative transcriptome sequencing to determine genes related to the nucellar embryony mechanism in citrus. *Turkish Journal of Agriculture and Forestry*, *43* (1), 58-68.
58. Spigler, R. B., Lewers, K. S., Main, D. S. & Ashman, T. L. (2008). Genetic mapping of sex determination in a wild strawberry, Fragaria virginiana, reveals earliest form of sex chromosome. *Heredity*, *101* (6), 507-517.
59. Tanksley, S. D., Young, N. D., Paterson, A. H. & Bonierbale, M. W. (1989). RFLP mapping in plant breeding: new tools for an old science. *Bio/technology*, *7* (3), 257-264.
60. Vining, K. J., Salinas, N., Tennessen, J. A., Zurn, J. D., Sargent, D. J., Hancock, J. & Bassil, N. V. (2017). Genotyping-by-sequencing enables linkage mapping in three octoploid cultivated strawberry families. *PeerJ*, *5*, e3731.
61. Wang, H., Cao, G. & Prior, R. L. (1996). Total antioxidant capacity of fruits. *Journal of agricultural and food chemistry*, *44* (3), 701-705.
62. Wei, N., Govindarajulu, R., Tennessen, J. A., Liston, A., Ashman, T. L. & Sayres, M. W. (2017). Genetic mapping and phylogenetic analysis reveal intraspecific variation in sex chromosomes of the Virginian strawberry. *Journal of Heredity*, *108* (7), 731-739.
63. Yoon, M. Y., Moe, K. T., Kim, D. Y., Rho, I. R., Kim, S., Kim, K. T., ... & Park, Y. J. (2012). Genetic diversity and population structure analysis of strawberry (Fragaria x ananassa Duch.) using SSR markers. *Electronic Journal of Biotechnology*, *15* (2), 6-6.
64. Zhang, Y., Li, W., Dou, Y., Zhang, J., Jiang, G., Miao, L., ... & Zhang, Z. (2015). Transcript quantification by RNA-Seq reveals differentially expressed genes in the red and yellow fruits of Fragaria vesca. *PloS one*, *10* (12).
65. Zorrilla-Fontanesi, Y., Cabeza, A., Torres, A. M., Botella, M. A., Valpuesta, V., Monfort, A., ... & Amaya, I. (2011). Development and bin mapping of strawberry genic-SSRs in diploid Fragaria and their transferability across the Rosoideae subfamily. *Molecular Breeding*, *27* (2), 137-156.