Harnessing the Benefits of Jute as Potherbs

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Authors’ contributions

This work was carried out in collaboration among all authors. Author AR designed the study, performed the statistical analysis, wrote the protocol and wrote the final draft of the manuscript. Authors DM and SH managed the field study; authors DM, KP managed the analyses in Laboratory. Authors AK and DM managed the literature searches and drafting of manuscripts. All authors read and approved the final manuscript.

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ABSTRACT

Demand for unconventional potherbs is increasing and known medicinal values or high content of Vitamin A or protein or Vitamin C will help jute to be equally popular as cheap sources of these. Walking on the paths of age-old belief on utilization of Jute as pat shak or potherbs (plant parts like leaves, flowers, stems, etc, that can be used in cooking or seasoning and flavouring) in some confined areas of India, the present study was undertaken with five varieties each of olitorius and capsularis grown in teaching Farm Mondouri, BCKV in Randomised Block Design (RBD) with four replications during 2018–2019 (4 rows of 4 m each) following recommended agronomic practices. Planting was done in first week of April month and were harvested after one month. Biomass traits like leaf length (cm), number of leaves per plant, leaf width (cm), petiole length (cm), plant height (cm), weight per plant (gm) were recorded along with an estimation of Vitamin A, Vitamin C and protein content in the leaves. In olitorius heritability was moderately high in all the traits except a number of leaves along with moderate Genetic Advance as per cent of Mean (GAM) for Leaf length. Fresh weight indicates that this may be due to additive gene effects and selection for these types of traits may be always rewarding. In capsularis heritability was moderately high for all traits except for the leaf length along with moderate GAM for petiole length and fresh weight indicates that this may

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be due to additive gene effects and selection for these types of traits may be rewarding. JRO 524 recorded high biomass yield along with high content of vitamin A (6950 IU (approximately 40 % of carrot) can serve as a cheap source of Vitamin A in the northeast provinces where it can be successfully taken as a vegetable as it happens to be one among the twenty-five popularly cultivated leafy vegetables (shaks) in West Bengal. Young jute leaves are flavorful and tender are rich in betacarotene, iron, calcium, and Vitamin C. Criteria of selection for improvement of yield can be taken in terms of wt g per 10 plants as suggested in capsularis and both wt of leaves and petiole size and no of leaves in case of olitorius. Also it can be stated that the traits like no of leaves and Leaf length are more affected by environmental variations in case of olitorius and the trait like plant height in case of capsularis. JRO 524 recorded high biomass yield along with high content of vitamin A (6950 IU approximately 40 % of carrot) can serve as a cheap source of Vitamin A in the northeast provinces where it can be successfully taken as a vegetable.

Keywords: Jute; potherb; vitamin A; vitamin C; protein; leaf weight.

1. INTRODUCTION

Jute dicotyledenos fibre-yielding plant of the genus Corchorus is one of the most important cash crops for the country, grown and known for the natural plant-based fiber. It is second important to cotton as fiber, but studies reveal that jute has equal potential in other fields or is a multifaceted crop, the potentials of which are yet to be utilized. Harvested young jute leaves are flavorful, tender and are rich in betacarotene, iron, calcium, and Vitamin C. The leaves at the tender age of 30 days are found suitable for nutritive and medicinal qualities gives wholesome utilization scope of this crop. Pre-formed vitamin A exists only in animal products. However, among 50 carotenoids beta-carotene is the most common carotenoid. The body can convert beta-carotene into vitamin A. The vitamin A content of foods is measured in retinol activity equivalents (RAE), and carotenoids measured in international units, or IU. Jute leaf is an important plant part that is a rich source of many chemical compounds. It plays an important role in the national and international markets. In 1940, Professor Tom D. Rowe has taken vital steps in the chemical analysis of the plant, [1]. It was found to be rich in vitamin, carotenoid, potassium, calcium, and dietary fiber. The bitter taste of C. capsularis L. is due to capsin, a glycoside. The leaves of C. olitorius has been known for the richness in potassium, iron, vitamin A, vitamin C, and vitamin B6 making this crop particularly important for a section of people getting a high share of their energy requirement from such micronutrient laden-poor staple crops. In light of present scenario of nutritional conscious consumers due importance may be attached to these type of crops which is already under cultivation. Keeping in view a study was undertaken for biomass traits and biochemical composition in the two cultivated species of jute for the people where a high share of their energy requirement are often supplied by micronutrient-poor crops. This may be take as a pilot study and more nutritional parameters to be included for further analysis.

2. MATERIALS AND METHODS

The experiment was conducted in the Teaching Farm located at Mondouri, Bidhan Chandra Krishi Viswavdyalay, Mohanpur, Nadia. The soils are well-drained sandy loam. The center experiences an annual average rainfall of approximately 1443.8 mm and an average daily temperature range of 27°C. In the present study five genotypes of Corchorus olitorious L. (JRO 8432, JRO 204, JRO 524, BCCO 6 and BCCO 13) and five genotypes of Corchorus capsularis L. (JRC 698, JRC 321, JRC 517, BCCC 1 and BCCC 2), were collected from AINP JAF, Kalyani center.

2.1 For Field

Freshly harvested seeds of the selected genotypes were taken. Plants were grown in Randomised Block Design with four replications during 2018 and 2019 in first week of April. Each entry was sown in four rows of four-meter length each with keeping 20 cm between rows and 2-3 cm within plant spacing. All the recommended agronomic practices were strictly followed. The fertilizer application was as per recommendation. (N: P₂O₅ = 40: 20, of which half Nitrogen and a full dose of P₂O₅ to be applied as basal and remaining Nitrogen to be applied as top-dressing after 21 days of sowing). Five competitive plants were selected randomly per row from each genotype for morphological as well as Biochemical studies (Vitamin A, Vitamin C, and
protein) from the same plants. The observation was taken for leaf length (cm), leaf width (cm), petiole length (cm), plant height (cm), weight per plant (gm), number of leaves per plant and, for leaf characters (it was taken for the fifth leaf from the top).

2.2 For Biochemical Studies Done in Laboratory

This was done with freshly harvested leaves of the selected genotypes after 30 days from those grown in the field for biomass study, since these traits may provide useful information about consumption as leafy vegetables. Biochemical contents were measured in the laboratory from the samples of 2019 and statistical analysis was carried out in Excel Sheet. The colorimetric and volumetric methods were used for vitamin A and vitamin C estimation respectively. Other than this protein was estimated by the Lowry method [2].

Analyses of variance ANOVA-- [3]; genetic parameters such as genotypic coefficient of variation (GCV) and PCV (Phenotypic coefficient of variation) [4], broad-sense heritability [5], and genetic advance as percentage of the mean [6] were calculated. For calculation of genotypic variance (Vg), phenotypic variance (Vp), heritability, genetic advance (GA), and Genetic Advance as percent Mean (GAM) ANOVA, GCV, and PCV were calculated using Microsoft Excel.

3. BIOCHEMICAL STUDY

3.1 Vitamin A Estimation

Instrumental analysis using HPLC is fast and accurate but expensive, however a rapid and colorimetric method to measure vitamin A was carried out.

3.2 Procedure: Extraction of Vitamin A

Grind 1 to 5 g of the sample material to a fine paste and 1.0ml of saponification mixture (2N KOH in 90% alcohol) was added. The tubes were refluxed gently for 20 min at 60 degree and cooled at room temperature; 20ml water was and mix well. Vitamin A was extracted with 10ml portion of petroleum ether in a separating funnel, twice. Pooling of the extract (organic layer) and add sodium sulphate (anhydrous) to remove the moisture for 30-60 min. Evaporate 5ml aliquot of that ether extract to dryness at 60 degree. Dissolve the dried residue in 1.0ml of chloroform.

3.3 Estimation

Pipette in aliquots in the concentration range 1.5-7.5 µg., making up the volume in each test tube to 1.0ml with chloroform., adding 2ml of TCA solution from a fast delivery pipette, rapidly mixing the contents of the tube. The absorbance was recorded, immediately, at 620nm in a spectrophotometer. A standard graph plotting the A620 in the Y-axis and vitamin A concentration in the X-axis was constructed and the amount of vitamin A/g tissue of the samples was determined.

3.4 Vitamin C Estimation

The volumetric method was used as it is easy, rapid and a large number of samples can be analysed in a short time.

3.5 Procedure

5 ml of the working standard solution was pipetted into a 100ml conical flask'.10ml of 4% oxalic acid was added and titrated against the dye (V1 ml). End point is the appearance of pink colour. The sample was extracted (0.5-5g depending on the sample) in 4% oxalic acid and make up to a known volume (100ml) and centrifuge. 5ml of this supernatant was taken and added 10ml of 4% oxalic acid and titrate against the dye (V2).

3.6 Calculation

Amount of ascorbic acid mg/100g sample

\[
\text{Amount} = \frac{0.5\text{mg} \times \frac{V_2}{5\text{ml}} \times \frac{100\text{ml}}{\text{W of the sample}}} {V_1}
\]

3.7 Protein Estimation

The method developed by Lowry et al. sensitive is enough to give a moderately constant value and largely followed. Protein content was determined by this method.

3.8 Procedure: Extraction of Protein from Sample

The sample is grind well with a pestle and mortar in 5-10ml of the buffer. Centrifuge and use the supernatant for protein estimation.

3.9 Estimation of Protein

0.2, 0.4, 0.6, 0.8 and 1ml of the working standard was pipetted into a test tube and the readings of
4. RESULTS AND DISCUSSION

In this study all the characters showed close values for the leaf width, it was found to be 4.8 and 4.46 cm for C. capsularis and C. olitorius. C. capsularis showed a bit narrower leaf at the same stage and leaf length was slightly more in C. olitorius 13.93 as compared to C. capsularis where it was 13.01 cm. However, the petiole length was more in C. olitorius 3.7cm. These contributed to more weight in the case of olitorius though the height was more in the case of C. capsular (107 cm against 102 cm in C. olitorius) at the same stage during the earlier period Table 1.

GCV was high (more than 20% for leaf weight) in the case of C. capsularis and moderate for C. olitorius with moderate to high GAM suggested that selection in this case based on the leaf weight must be rewarding Table 2.

Here it was found that in the case of C. olitorius all the characters under study except several leaves showed significance and heritability was moderately high in all the traits except no of leaves along with moderate GAM for Leaf length and fresh weight. However, for C. capsularis except for leaf length, all the characters were significant. Similarly heritability was moderately high for all traits except the leaf length along with moderate GAM for petiole length and fresh weight. may be due to additive gene effects and selection for these traits may be rewarding. Mostly, the value of the Phenotypic coefficient of variation (PCV) was slightly higher than the genotypic coefficient of variation (GCV) value in all the characters. This may be suggested by the slight environmental effect on the phenotype of all the other characters. This report corresponds to the report of Denton and Nwangburuka [7], Nwangburuka et al. [8], Yadav et al. [9], and Mohammed et al. [10] who observed slight differences between Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) in characters which were studied in solanum anguivi, okra, rice, ethiopian durum wheat and in seven out of sixteen characters, respectively. The GCV and PCV provides a measure to compare the variability present in the traits. The GCV especially helps to compare the genetic variability in the traits. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) indicates the presence of high genetic variability for the traits which may facilitate selection [11]. The broad-sense heritability can be used as a predictor in the selection procedure [12]. Also [13] and Ibrahim and Hussein [14] suggested that the prediction of the response of an individual to selection is more reliable when the genotypic coefficient of variation (GCV), estimates of broad-sense heritability, and genetic advance are combined. When the Genetic Advance (GA) is high then the heritability is mostly due to the additive gene effect [15].

Criteria of selection for improvement of yield can be taken in terms of wt g per 10 plants as suggested in capsularis and both wt of leaves and petiole size and no of leaves in case of olitorius as found in Table 2. Also it can be stated that the traits like no of leaves and Leaf length are more affected by environmental variations in case of olitorius and the trait like plant height in case of capsularis. Considering both the sp. wt of plants at harvest stage is the only acceptable character with high heritability.

From Table 3 it was found that Heritability, GAM, GCV in case of trait Vitamin A was 80.60, 27.54, 14.89, for Vitamin C was 96.50, 22.21, 10.98 respectively in olitorius, which indicates its highly heritable nature. In this case the protein content was found to be under environmental influence. In case of capsularis the values were found for Vitamin C as 96.70, 25.47, 12.58 and protein as 90.20, 45.96, 23.54 respectively. High heritability coupled with GAM and moderate to high, GCV respectively are under additive gene effect and it will be effective in accurate prediction of yield
components. In the case of olitorius the varieties differed significantly for Vitamin A and C content whereas for capsularis it varied for Vitamin C content. It was found that Mitha pat or dark jute had high Vitamin A content 5780 IU, Vitamin C 280 mg/gm, and protein as 4.11 gm/100 gm leaves, whereas the nutritive content was less in white or lighter jute high Vitamin A content 3087 IU, Vitamin C 156 mg/gm and protein as 3.76 gm/100 gm leaves, highest Vitamin A and Vitamin C was found in JRO 524 and protein in JRO 204 at 30-35 DAS as represented in Fig. 1. So C olitorius can be taken as a good source of Vitamin A, Vitamin C and protein wherein case for Vitamin A further improvement based on selection can be carried out.

4.1 Economics of Production: Per ha

Land preparation and Sowing: Rs 3500.00, Fertiliser, Labour involved: Rs 25000.00, Irrigation and Misc: 3000.00, Total: Rs 31500.00, Production: 4-5t of jute as pot herb @ 15.00 rs/kg: 67500.00. Within a span of 1 month utilizing the lean periods after the rabi crop and before proceeding for the subsequent Kharif crop

Benefit: Cost Ratio –1.06, if the jute as pot herb is popularised then the price can be raised to Rs20-25per kg. At present this is just obtained from what comes out as a part of thinning so that there 1/5 the of the population is reduced which maybe 2-5t and if properly taken into consideration may fetch a substantial amount of Rs 15000.00 to cover the expense of the man-days employed for weeding in otherwise jute crop for fibre purpose.

Table 1. Mean performances of biomass traits for leafy vegetables production

| Variety   | LW (cm) | LL (cm) | PL (cm) | PH (cm) | No of leaves | WT(g) | Yield kg/ha |
|-----------|---------|---------|---------|---------|--------------|-------|-------------|
| JRO 8432  | 4.56    | 12.59   | 3.60    | 104.90  | 20.30        | 54.72 |             |
| JRO 204   | 4.61    | 13.31   | 3.43    | 104.89  | 22.58        | 55.90 |             |
| JRO 524   | 4.65    | 13.37   | 3.87    | 104.14  | 21.13        | 63.95 |             |
| BCCO 6    | 5.17    | 14.65   | 3.84    | 98.32   | 20.56        | 48.58 |             |
| BCCO 13   | 5.34    | 15.77   | 3.79    | 102.05  | 21.85        | 68.18 |             |
| Mean      | 4.86    | 13.94   | 3.71    | 102.86  | 21.28        | 58.26 |             |
| JRC 698   | 4.47    | 13.61   | 3.79    | 113.60  | 21.60        | 63.85 |             |
| JRC 321   | 4.34    | 12.83   | 2.84    | 108.79  | 20.90        | 60.11 |             |
| JRC 517   | 4.62    | 13.11   | 2.83    | 104.95  | 21.50        | 54.95 |             |
| BCCC 1    | 4.41    | 12.76   | 2.50    | 104.93  | 19.33        | 48.75 |             |
| BCCC 2    | 4.50    | 12.77   | 2.77    | 106.25  | 19.08        | 60.00 |             |
| Mean      | 4.47    | 13.01   | 2.95    | 107.70  | 20.48        | 57.53 |             |

LW –leaf width, LL - leaf length, PL--petiole length, PH – Plant height in cm, WT – weight

Table 2. Genetic analysis of biomass traits

| C. olitorius | LW | LL  | PL  | PH  | No of leaves | WTg /10 plants |
|--------------|----|-----|-----|-----|--------------|----------------|
| Mean         | 4.8645 | 13.9395 | 3.7050 | 102.8605 | 21.2825 | 58.2645 |
| CV           | 4.0070 | 5.0205 | 3.3379 | 1.4917  | 4.2021 | 1.3013 |
| CD           | 0.300  | 1.078 | 0.191 | 2.364  | 1.378  | 1.168  |
| SE           | 0.138  | 0.495 | 0.087 | 1.085  | 0.632  | 0.536  |
| Heritability%| 76.2  | 75.0  | 66.8  | 75.4  | 45.7  | 99.1  |
| GA           | 0.62   | 2.17  | 0.3   | 4.8   | 1.145  | 15.95 |
| GCV%         | 7.14   | 8.71  | 4.74  | 2.61  | 3.86  | 13.35 |
| PCV%         | 8.18   | 10.06 | 5.80  | 3.01  | 5.71  | 13.41 |
| GAM          | 12.848 | 15.531 | 7.989 | 4.66  | 5.375 | 27.378 |
C. olitorius

|      | LW | LL | PL | PH  | No of leaves | WTg / 10 plants |
|------|----|----|----|-----|--------------|-----------------|
| C. capsularis | 4.4665 | 13.0145 | 2.9455 | 107.702 | 20.48 | 57.532 |
| CV  | 2% | 5% | 3% | 2% | 2% | 1% |
| CD  | 0.161 | 1.086 | 0.137 | 3.779 | 0.495 | 1.293 |
| SE  | 0.074 | 0.498 | 0.063 | 1.734 | 0.227 | 0.594 |
| Heritability% | 42.4 | 1.3 | 96.8 | 66.3 | 93.2 | 98.0 |
| GA  | 0.12 | 0.02 | 0.99 | 5.77 | 2.37 | 11.88 |
| GCV% | 0.0080 | 0.0063 | 0.2407 | 11.8341 | 1.4190 | 33.9349 |
| PCV% | 0.0189 | 0.5031 | 0.2485 | 17.8505 | 1.5223 | 34.6397 |
| GAM | 2.68 | 0.153 | 33.61 | 5.35 | 11.57 | 20.65 |

Table 3. Mean performance and genetic parameters for biochemical contents in C. olitorius

| Vitamin A (IU / 100 gm sample) | Vitamin C (mg/100 gm sample) | Protein (g/100 gm sample) |
|---------------------------------|-----------------------------|--------------------------|
| C. olitorius | C. capsularis | C. olitorius | C. capsularis | C. olitorius | C. capsularis |
| Mean | 5780 | 3087 | 285.167 | 156.199 | 4.116 | 3.764 |
| Max | 6950 | 3295 | 288.06 | 174.27 | 4.74 | 4.09 |
| Min | 4577.50 | 2875 | 258.87 | 123.67 | 3.55 | 2.23 |
| CV | 7.3002 | 5.047 | 2.101 | 2.329 | 14.404 | 7.769 |
| SE | 0.298 | 0.110 | 0.423 | 0.257 | 0.419 | 0.206 |
| Heritability% | 80.60 | 49.80 | 96.50 | 96.70 | 19.90 | 90.20 |
| GA | 1592.36 | 225.88 | 63.34 | 39.79 | 22.21 | 1.73 |
| GCV% | 14.89 | 5.03 | 10.98 | 12.58 | 7.17 | 23.54 |
| PCV% | 16.59 | 7.13 | 11.18 | 12.79 | 16.09 | 24.79 |
| GAM | 27.54 | 7.317 | 22.21 | 25.47 | 6.559 | 45.96 |

Fig. 1. Comparative representation of the nutritional contents in C. olitorius and C. capsularis

5. CONCLUSION

This study will be useful for the production of leafy biomass which can be a source of several medicinal or biochemical compounds. Considering the low cost of cultivation along with fast growth this should be very well promoted as a leafy vegetable with 30 days span during the Kharif and the leaves can be utilized for the production of some processed products like herbal tea, tablets etc. JRO 524 recorded high biomass yield along with high content of vitamin A (6950 IU approximately 40 % of carrot) can serve as a cheap source of Vitamin A in the northeast provinces where it can be successfully taken as a vegetable. Vitamin A may vary from 6300 IU in spinach, 17000 in carrot, which is even more in pumpkin up to 43500 as reported in
moschata variety Baianinha., Vitamin A requirement is 900 mcg for adult men to 700 mcg for adult women (B carotene 1IU =0.05 mcg RAE). Jute as potherb can be successfully recommended for use to fulfill the nutritional requirement.

Vitamin A – Absorption study: Generally eating vegetables that are high in carotenoids with some amount of fat has been shown to increase both the absorption and synthesis of vitamin A [16]. Many factors affect the absorption of dietary carotenoids and its conversion to vitamin A, including body composition, age, smoking, medications and genetic variation [17]. Also s 50% of individuals in some populations may have a low response to as beta-carotene and other carotenoids, [18]. In that context researchers are looking into how genetic variability impacts the conversion of carotenoids into vitamin A [19]. However, still, the amount of provitamin A carotenoids that is optimal for a low responder who relies exclusively on carotenoids is not known but choosing a generous amount of foods that contain beta-carotene and another provitamin A carotenoids may lead to greater absorption and more conversion in low-responders [20]. Until more is known, best advice is to meet the intake recommendations for provitamin A carotenoids by eating generous amounts of vegetables, leafy green carrots, sweet potatoes, bright orange, and winter squashes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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REFERENCES

1. Calleja, Danny O. Saluyot now a popular vegetable worldwide. Inquirer; 2010. Retrieved August 7, 2011.

2. Sadasivam S, Manickam A. Biochemical Methods. New Age International (P) Limited. Sivasubramanian S and Madhava Menon P. Genotypic and phenotypic variability in rice. Madras Agric. J. 2007; 60(9-12):1093-96.

3. Panse VG and Sukhatme PV. Statistical Methods for Agricultural Workers. ICAR, New Delhi. 1967;2:381.

4. Burton GW. Quantitative inheritance of grasses. Proc. 6th Intern. Grassland Congress. 1952;1:277-283.

5. Burton GW and De Vane EH. Estimating heritability in tall fescue (Festuca arundinacea) from replicated clonal material. Agron. J. 1953;45:478-481.

6. Johnson HW, Robinson AE and Comstock RE. Estimates of genetic and environmental variability in soybeans. Agron. J. 1955;47:314-318.

7. Denton OA, Nwangburuka CC. Heritability, genetic advance and Character association in Six Yield related characters of Solanum anguivi. Asian J of Agricultural Research. 2011;5 (3):201-207.

8. Nwangburuka, CC, Denton OA, Kehinde OB, Ojo DK and Popoola AR. Genetic variability and heritability in cultivated okra [Abelmoschus esculentus (L.) Moench]. Spanish Journal of Agricultural Research. 2012;10(1):123-129.

9. Yadav P, Rangare NR, Anurag PJ and Chaurasia AK. Quantitative analysis of rice (Oryza sativa L.) in Allahabad agroclimatic zone. J. of Rice Res. 2010;3:16-18.

10. Mohammed A, Tesso B, Ojiewo C and Ahmed S Assessment of Genetic variability and heritability of agronomic traits in Ethiopian chickpea (Cicer arietinum) landraces. Black Sea Journal of Agriculture. 2019;2(1):10-15.

11. Yadav RK. Studies on genetic variability for some quantitative characters in rice (Oryza sativa L). Advan.s in Agric. Res. 2000;13:205-207.

12. Allard RW. Principles of Plant Breeding. John Wiley and Sons Inc., New York 1960;485.

13. Ghandi SM, Sanghai AK, Nathawat KS and Bhatnagar MP. Genotypic variability and correlation coefficient to grain yield and a few other quantitative characters in Indian wheat. Indian J. Genet. Plant. Breed. 1964;24:1-8.

14. Ibrahim MM and Hussein RM. Variability, heritability and genetic advance in some genotypes of roselle (Hibiscus sabdariffa L.) World J. Agric. Sci. 2006;2:340-245.

15. Percy RG and Turcotte EL. Inheritance of male-sterile mutant ms13 in American Pima cotton. Crop Sci. 1991;31:1520-1521.
16. Kopec RE, Cooperstone JL, Schweiggert RM, Young GS, Harrison EH, Francis DM, Clinton SK, Schwartz SJ. Avocado Consumption Enhances Human Postprandial Provitamin A Absorption and Conversion from a Novel High-β-Carotene Tomato Sauce and from Carrots. J Nutr. 2014;144(8):1158-66.

17. Moran NE, Mohn ES, Hason N, Erdman JW Jr, Johnson EJ. Intrinsic and extrinsic factors impacting absorption, metabolism, and health effects of dietary carotenoids. Adv Nutr. 2018;9(4):465-492.

18. Lietz G, Oxley A, Leung W, Hesketh J. Single nucleotide polymorphisms upstream from the β-carotene 15,15′-monooxygenase gene influence provitamin A conversion efficiency in female volunteers. J Nutr. 2012;142(1):161S-5S.

19. Borel P, Desmarchelier C. Genetic variations associated with vitamin A status and vitamin A bioavailability. Nutrients. 2017;9(3).

20. Borel P, Desmarchelier C, Nowicki M, Bott R. A combination of single-nucleotide polymorphisms is associated with interindividual variability in dietary β-carotene bioavailability in healthy men. J Nutr. 2015;145(8):1740-7.