A Seminar Paper on

Breeding for Quality Traits in Mustard (*Brassica* sp.)

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ABSTRACT

Mustard (*Brassica* sp.), the third most important source of vegetable oil in the world is grown in more than 50 countries across the globe. Mustard oil contains various saturated and unsaturated fatty acids. High erucic acid in oil and glucosinolate in seed meal are considered as anti-nutritional factor. One important approach towards this is to develop *Brassica* germplasms having low undesirable fatty acids by transferring the potential genes, preferably from the superior species into the cultivated ones through efficient breeding programmes. Canola (00) varieties have oil content with less than 2% erucic acid and glucosinolates of less than 30 μmoles/g defatted seed meal and command a premium in the international market. In this study, among the cultivars of three *Brassica* species developed in Bangladesh, the contents of erucic acid varied considerably ranging from 21.59 to 51.57%. Among them, Binasarisha-3, Binasarisha-4, Binasarisha-5 and advanced lines of MM 22-12-98, MM 2-16-98, MM 36-6-98, MM 49-3-98, MM 34-7-98 and Barisarisha-8 of *B. napus* had low levels of erucic acid and high levels of oleic, linoleic and linolenic acids. Some populations among different cultivars such as Tori-7×BARI sarisha-15, BARIsarisha-9× BARIsarisha-6 and SAUsarisha-1× BARI Sarisha-15 able to fulfill the requirement, may be exploited in plant breeding programmes for development of nutritionally better quality locally adaptive cultivars.

Keywords: Erucic acid, Glucosinolate, Germplasm, Canola.

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CHAPTER 1

INTRODUCTION

Mustard (*Brassica* sp.), the third most important source of vegetable oil in Brassicaceae family is cultivated in more than 50 countries (Meena *et al*., 2022). In Bangladesh, mustard is one of the most important oil crops, contributing for over 80% of the country's total oilseed area. It is currently ranked 1st among oilseed crops in Bangladesh and second largest oilseed crop worldwide, behind soybean (FAO, 2014). Although it is native to the Mediterranean region, it is now widely cultivated elsewhere in the world. Of all the oilseed crops, mustard is the preferred source of vegetable oil and holds a dominant position in the world. It is also used as animal feed, manure, condiments, and has a variety of industrial applications (Kumar *et al*., 2013).

Mustard seed generally contains 35–45% oil, 17–25% proteins, 8–10% fibers, and 6–10% moisture (Rathod *et al*., 2020). Seed meal extracted from oil is a good source of vitamins, minerals, and high-quality proteins. Moreover, different saturated and unsaturated fatty acids are abundant in *Brassica* species (Mitiku *et al*., 2022). In mustard oil, saturated fatty acids (SFAs) include palmitic acid, whereas polyunsaturated fatty acids (PUFAs) like omega-3- alpha-linolenic acid and omega-6- linoleic acid and monounsaturated (MUPAs) like erucic acid and oleic acid are nutritionally significant. The presence and absence of these fatty acids determine the nutritional quality of the edible oils (Iqbal *et al*., 2019). Erucic acid in oil and glucosinolate in deoiled cake when present at high concentration become nutritionally toxic to consume (Chauhan *et al.*, 2011). Mustard oil in many countries, due to higher amounts of erucic acid (35.7–51.4%), higher amounts of glucosinolates (upto 300 μmol/g in the deoiled meal) and low amounts of oleic acid (10-15%) (Chowdhuri *et al*., 2010) have limited preference in international market.

Earliar studies reported consumption of high erucic acid in the diet is known to cause impaired myocardial conductance, myocardial fibrosis, lipidosis, and increased blood cholesterol (Shekhawat *et al*., 2014). Higher amount of palmitic acid in edible oil leads to increased serum cholesterol (Kumar *et al*., 2014). Apart from improvement in productivity, another important objective in Brassica breeding is the improvement of oil and meal quality through the development of quality (low erucic acid and glucosinolates), high oleic, low PUFA (Poly-unsaturated fatty acid) and yellow seeded cultivars (Chauhan *et al*., 2007).

Thus, it is imperative to create Brassica cultivars with low levels of erucic acid that may be utilized for edible uses in order to achieve the quality standards. Increased oleic and linoleic acid levels and decreased linolenic acid levels in the edible oil should be another essential goal in addition to monitoring erucic acid levels (Abbadi *et. al*., 2011). Developing Brassica germplasm with low undesired fatty acids by transferring the prospective genes, ideally from the wild species into the cultivated ones through effective breeding programs, is a key strategy in this direction (Sharma *et al*., 2007). Keeping this in consideration, the current study was aimed to assess the fatty acid composition and oil content of several *Brassica juncea, Brassica rapa, and Brassica napus* varieties as well as to determine how these features vary within the species. As a result, numerous attempts to create cultivars free of those undesirable traits have been made. Already breeders have been successful in creating "Canola," or "00" quality rapeseed, over the previous 20 years (Hossain *et. al*., 2018).

Objectives:

- To find out the traits having positive contribution to quality of mustard
- To assess available low erucic acid/low glucosinolate lines of different *Brassica* sp. For quality improvement

CHAPTER 2

MATERIALS AND METHODS

The seminar paper is absolutely a review paper. Therefore, no specific methods of studies are followed to prepare this paper. All the information and data collected from secondary sources. The title is selected with the consultations of my major professor. The seminar paper has been prepared by reciting different journals, booklets proceeding and consultancy report which are available in libraries of BSMRAU and internet. Some information is also collected from the website of BARI, BRRI and some private agricultural organizations. Maximum necessary supports have been taken from internet searching. Finally, this seminar paper was prepared with the consultation of my respective major professor and honorable seminar course instructors.

CHAPTER 3

REVIEW OF FINDINGS

3.1 Quality Characteristics of Mustard

The oilseed crop mustard is recognized for the quantity and quality of oil and protein in the seed. One of the most remarkable characteristics of *Brassica* species is the high oil content in the seeds, ranging from about 17->40%**.** Protein content of mustard seed ranged from 17.8-22.0% (Bhardwaj *et al*., 2000). The quality of mustard not only measured by oil and protein content of the seed but also it depends on the composition of fatty acids in mustard oil (both saturated and unsaturated) and nutrient quality of the oilcake. The quality characters should be considered by the breeders for the improvement of quality traits in mustard are-

1. Oil Quality
2. Seed Meal Quality

3.1.1 Status of Quality Improvement Programme in *Brassica* sp.

Several strains of low erucic and low glucosinolate content have been registered with the National Bureau of Plant Genetic Resources (ICAR), New Delhi. Five low-erucic acid mustard cultivars have been found for release as of December 2010; the first was Pusa Karishma (LES 39) in Delhi state, 2004 (Meena *et al*., 2022). According to the National Oilseeds and Vegetable Oils Development Board, the first Brassica napus strains with ‘0’ erucic acid was developed in 1961. Several researchers refer to these cultivars as "double low" or "double zero". "Bronowski," of *B. napus* with a glucosinolate content of around 12 µmol/g oil-free meal, was identified in 1967. Moreover, the seed oil includes comperatively lower concentration of erucic acid (7–10%). Having low glucosinolate content, the "Bronowski" gene has been exploited to create canola cultivars of superior quality (Canola Council of Canada, 2022). *Brassica campestris* variants devoid of erucic acid were introduced as canola oil became more and more popular. In order to satisfy the existing demand for canola quality mustard oil and to take advantage of the commodity's developing trade potential, it is imperative to increase the area and production of canola type mustard.

3.1.2 Oil Quality:

Quality of mustard oil denotes high amount of mono-unsaturated fatty acids, a good ratio of polyunsaturated fatty acids, relatively high level of oleic acid and a favorable balance between linolenic and linoleic acids. Fatty acids present in mustard oil are both saturated and unsaturated types. It contains the least amount of saturated fatty acids i.e. less than 10%, making it safe for heart patients. Adults and children should consume a maximum of 10% of their total energy intake in the form of saturated fat to reduce the risk of heart disease (WHO, 2018).

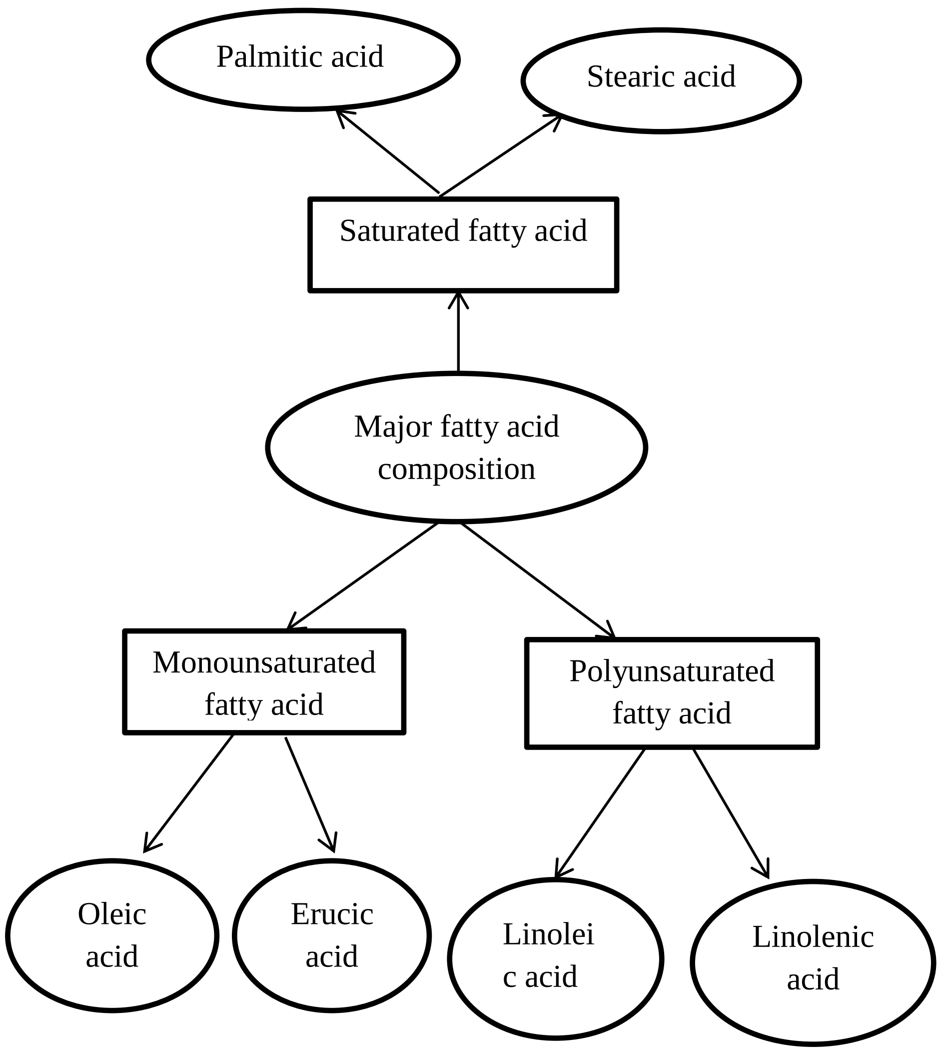

Figure 1. Major fatty acid constitutions in mustard.

3.1.3 Criteria for Good Quality Mustard:

Oil and seed meal should be free or at non-toxic levels of anti-nutritional constituents including erucic acid <2% in edible oil and glucosinolate <30 µgm defatted seed meal (Ko *et al*., 2017). Mustard oil should contain <7% saturated fatty acids as higher concentration of saturated fatty acids in the edible oil is harmful for human health. Development of varieties with low percentage of erucic, palmitic, stearic acid and high percentage of oleic, linoleic, linolenic acid is main concern for mustard breeding nowadays.

Table 1. Optimum range of different fatty acids in mustard oil

Different fatty acids	Degree of range	Source
Saturated fatty acid	<7%	Warner et al.1997
Oleic acid	Upto 70%	Warner et al.1997
Linoleic acid	23-37%	Warner et al.1997
Linolenic acid	<3%	Warner et al.1997
SFA:MUFA:PUFA	1:1.3:1	Mawlong et al. 2015
Linoleic/Linolenic	5-10	Mawlong et al. 2015
Palmitic	1-3	Kumar and Chauhan 2010
Stearic	1-3	Kumar and Chauhan 2010
Eicosenoic	4-15	Kumar and Chauhan 2010
Glucosinolate	<30µmol/g	Thacker 1990
Erucic	<2%	Thacker 1990

SFA= Saturated Fatty Acid; MUFA= Mono-Unsaturated Fatty Acid; PUFA= Poly-Unsaturated Fatty Acid

Source: Kaur *et al*., 2019

3.1.4 Effects of Different Fatty Acids

High erucic acid in oil and glucosinolate in seed meal is an anti-nutritional factor. They have many adverse effects on both human and animal when present at high concentration.

Table 2. Effects of different fatty acids on human and animal

Fatty acids constitution	Acceptance for human	Effects	Sources
High erucic acid	Undesireable	Cause Impaired myocardial conductance and myocardial fibrosis, lipidosis, and increased blood cholesterol	Kaur *et al*., 2019
High Oleic acid	Desireable	Lowers blood cholesterol	Patel *et al*., 2015
High palmitic and stearic acid	Undesireable	Raise blood cholesterol	Sharafi *et al*., 2015
High linoleic acid	Desireable	Reduces blood cholesterol and prevents atherosclerosis	Kaur *et al*., 2019
High linolenic	Undesireable	Cause rancidity, off flavor reduced shelf life of the oil	Sharafi *et al*., 2015
High glucosinolate	Undesireable	High pungency in oil, Anti-nutritional for animal consumption	Bhardwaj *et al*., 2000

3.1.5 Diversified Usage of Mustard Oil

Each fatty acid should be at optimum range for better nutritional quality. Besides, when those fatty acids present at high concentration can be used for industrial purposes also. Different types of modified fatty acids are developed by breeders according to the requirement which are used both for human consumption and industrial purposes.

Table 3. Diversified usage of mustard oil with modified fatty acid composition

Modified fatty acid composition	Use
Zero erucic acid (<2%)	Nutritionally superior
High erucic acid (40-55%) Or (>80%)	Industrial polymers, lubricants, plastic industry
High stearic acid (20-40%)	Cosmetics, pharmaceuticals
Low glucosinolate	Poultry and fish feed
Epoxy fatty acids	Resins
Wax esters	Cosmetics, lubricants
Very low linolenic acids (<3%)	Prolonged shelf life
High linoleic acid (40-50%)	Nutritionally superior
Oleic acid (upto 70%)	Nutritionally superior

Chauhan *et al*., 2011

3.1.6 Seed Meal Quality

Although, oil content is the major quality parameter, seed meal protein content is also very important as it can be used to eliminate protein malnutrition in animals. After extraction of oil, the remaining portion of seed is known as seed meal. Seed meal of oilseed crops is a rich source of protein (35-40%) and crude fibre (10-12%) (Mitiku *et al*., 2022). Mustard seed meal also contains high amount of glucosinolates (120 µmole/g defatted seed meal), the hydrolysis products of which have been reported to be detrimental to animal health, particularly in nonruminants, as they reduce the feed palatability, adversely affect the iodine uptake by the thyroid glands and thus reduce feed efficiency and weight gains (Bhardwaj *et al.*, 2000). The recommended concentration of glucosinolates is <30µmole/g defatted seed meal (Kumar *et al*., 2014). Mustard seed meal also contains ash (4–6%), minerals and vitamins (1.0–1.5%), tannins(1.6–3.1%), sinapin (1.0–1.5%) and phytic acid (3–6%) where Glucosinolates, fibres, tannins, phytic acid, and sinapin all reduce feed value of seed meal (Abbadi *et al,* 2011).

Table 4. Major glucosinolate present in different primary and originating species of oil seed

Species	Major glucosinolate component
B. juncea	Sinigrin, gluconapin
B. carinata	Sinigrin
B.napus	Progoitrin
B. campestris	Gluconapin, glucbrassicanapin, glucobrassicin
B. nigra	Sinigrin
B. oleracea	Progoitrin

Source: Chauhan *et al*., 2002

Breeding efforts have been underway since 1970 to reduce glucosinolate content in the seed of mustard varieties up to 30 micro moles/g defatted seed meal and erucic acid up to 2% as well as combining both to develop double zero or double low varieties to meet the internationally acceptable standard of oil and seed meal. The current efforts are to recombine low erucic acid with low glucosinolate content in mustard and refining the agronomic base to improve yield potential of double low cultivars.

3.2 Contribution of Breeding

Apart from improvement in productivity, another important objective in *Brassica* breeding is the improvement of oil and meal quality through the development of canola quality (low erucic acid and glucosinolates), high oleic, low PUFA (Poly unsaturated fatty acid) and yellow seeded cultivars. Majority of these quality traits are available in the exotic east European germplasm (Ko *et al*., 2017). As all the cultivars grown in Bangladesh are brown seeded and high in both erucic acid and glucosinolates, these quality improvements could be brought about only through the transfer of the desirable genes either from the exotic germplasms or wild types which contain quality traits. In addition to the low erucic acid and low glucosinolate, yellow seed coat colour is another desired characteristic nowadays. During recent years the concept of ‘00' is being expanded to ‘000' to include this as one of the major breeding objectives. Based on presence of fatty acids quality can be categorized as-

Single Zero (Single Low) varieties: Varieties with low erucic acid content (>2%), but high glucosinolate content in seed meal.

Double Zero (Double Low or Canola): Varieties having oil with Varieties having oil with <2% erucic acid and glucosinolates <30 µ moles/g in defatted seed meal are termed as “Canola” (00). The increasing popularity of canola quality oil led to the introduction of *Brassica campestris* strains with no erucic acid. In 1967, the cultivar ‘Bronowski' of *B. napus* was identified, with a glucosinolate concentration of roughly 12 mol/g oil-free meal. It also has a low level of erucic acid in the seed oil (7–10%). As a result, the ‘Bronowski' gene is the source of low glucosinolate content, which has been used to develop high-quality canola cultivars.

Canola has the following characteristics:

1. Higher yield with < 2% erucic acid.
2. Relatively shorter duration of the crop.
3. Perceived as a healthy cooking medium having less than 2 percent erucic acid.
4. Demand as livestock feed as oil meal contains less than 30 micromoles glucosinolates per gram of defatted meal.
5. Used as salad oil for its light colour and texture.
6. Used in baking industry (reduces the saturated fatty acid intake, modifies the texture of baked product by making it more moist and softer).

Triple Zero: A triple variety is a double low with yellow coat color as a quality trait contains better meal quality due to low crude fibre content.

3.3 Quality Strain in Mustard

Initially, the most popular method for converting traditional varieties into canola types was hybridization together with pedigree selection. By using embryo rescue and extensive hybridization, several economically significant features were transferred, including double low, high oil content, and shattering tolerance in *B. napus*, and low erucic/high oleic acid, yellow seed coat color, double low, and resistance to fungi in *B. juncea*. Subsequently, breeders were able to quickly create a huge number of new gene combinations with desired features by using interspecific and intergeneric crosses (Wanasundara, 2018). In order to increase the yield potential of double low strains, efforts are currently being made to recombine low erucic acid with low glucosinolate content in mustard (Chauhan *et al*., 2011). In recent years, more sophisticated technologies have revolutionized quality breeding, including mutagenesis, marker-assisted selection (MAS), and genetic engineering (transgenic) (Barve *et al.*, 2009).

Table 6. Enhanced quality strains registered at ICAR

Crop	Strain	Specific Traits
B. napus	TERI-Uttam	High oil content, zero erucic canola quality, early maturing
B. juncea	TERI-Uphaar	High oleic and linoleic acid, yellow seeded, double low
B. napus	TERI-Gaurav	Early maturing, dwarf, double low
B. napus	TERI-Garima	High oleic acid, double low
B. napus	TERI-Shyamali	Low erucic acid, high oleic
B. napus	TERI-Phaguni	Low erucic-acid, early maturing
B. juncea	TERI-Swarna	Low erucic acid, yellow seeded, early maturing

Source: Rathod *et al*., 2020

3.4 Exotic Sources of Quality Traits in Mustard:

The majority of research efforts are directed at finding potential donors for desirable traits that will be used in the breeding program. For canola-like properties, many such donors have previously been discovered, and efforts are still being made in this direction. In the breeding programme, Australian and Chinese double low lines have been employed extensively, and they already prove to be very valuable in the future. JR-042, JN-010, JN-033, JN031, JN-049, JN-009, JN-004, JN-028, JM-16, and JM-006 are Australian lines, whereas CBJ-001, CBJ-002, CBJ-003, CBJ004, and XINYOU-5 are Chinese lines (Canola Council of Canada, 2022. Here Table 5 provides a list of some of the acknowledged sources of these desirable qualities in mustard. These potential donors are expected to be used for the development of canola variants both in *Brassica napus* and *Brassica juncea.*

Table 5. Sources for canola quality traits

Quality charactes	Promising donors
Low erucic acid and high oleic acid (single low)	*B.juncea*: LES 39
High oleic and linoleic acid (double low)	*B. juncea*: TERI Uphaar (TERI GZ-05)
Glucosinolate content less than 30 µmole/g defatted meal	*B. juncea*: NUDH-YJ-1, NUDH-YJ-2 *B. napus*: HNS 99(0E)3, NUDB-09, NUDB-26-11
Low erucic acid (up to 2%)	*B. juncea*: LES 17-1, LES 21, LES 38, LET-14, LET-17, YSRL 9- 18 -23, TERISwarna [TERI (OE) M 21] *B. napus:* NUDB-26-11, Phaguni [TERI (0E) R 03], Shyamali [TERI (0E) R 09]
Low erucic acid (< 2%) and low glucosinolate (< 30 µmoles/g fat free meal)	*B. juncea*: Heera, NUDHYJ- 5 *B. napus*: OCN-3 (GSC -6), NUDB-26- 11, NUDH-07, BCN 14, CAN 138, GSC 5 (GSC 3A), TERI-Garima [TERI(00) R985], TERI-Gaurav [TERI(00) R 986], TERIUttam [TERI(00) R 9903]

Source: Meena *et al*., 2022

3.5 Performance of Advanced Mustard Line

Seven strains of cultivated mustard variety were evaluated for seed yield and quality characters having both zero and high erucic acid, high oleic and a '00' strain.

Table 7. Performance of ‘0’ and ‘00’ *B.napus* lines developed in India through hybridization

Strains	Yield kg/ha	Oil content (%)	Quality status
GSL 6001	1662	40.2	‘00’ Low erucic and glucosinolate
GSL 6016	1440	41.6	‘0’ Low erucic
GSL 8814	1603	43.7	‘0’ Low erucic
GSL 8884	1492	41.4	‘00’ Low erucic and glucosinolate
GSL 9001	1296	40.8	High erucic acid
GSL 1 (Check)	1296	40.8	High erucic acid

Source: Chauhan *et al.*, 2002

Here the strains GSL 6001 had highest yield over the check although it had ’00’ status. For high yielding along with ‘00’ quality it can be used in breeding program. Moreover, GSL 8884 enriched with oil content with low erucic acid over check.

3.6 Mustard breeding in Bangladesh:

Precise evaluation of available gene pool and dissemination of findings is imperative for quality development in mustard. Successful variety development programme needs continuous supply of resource genes for crop yield, quality. In our country, back cross method is most widely used for quality improvement in this crop. Inter-specific methodology was also successful for the enhancement of yield and seed quality in the development of *Brassica* sp. For developing promising varieties through hybridization a careful choice of parents and breeding methodology are matters of great concern to a plant breeder.

3.6.1 Quality performance of Some Mustard Cultivars Developed in Bangladesh

The oil content of different varieties and advanced lines of mustard seeds were varied from 40.05% to 42.25% (Table 6). The variety BARI Sarisha-12 had the lowest amount of oil contained (40.05%) while the variety BARI Sarisha-14 contained significantly highest amount of oil (42.25%), followed by BARI Sarisha-17 (41.98) and advanced lines Din-2 (41.86%) and BC-2193 (41.34%). The results clearly indicated that variety BARI Sarisha-14, BARI Sarisha-17 Din-2 and BC-2193 can be considered as better source of oil for further breeding program.

Table 8. Oil and protein content of different varieties and advanced lines of *Brassica*

Name of variety	Oil content (%)	Protein (%)
BARI Sarisha-9	40.53	29.25
BARI Sarisha-12	40.05	29.69
BARI Sarisha-14	42.25	25.06
BARI Sarisha-15	40.75	28.44
BARI Sarisha-16	40.95	26.60
BARI Sarisha-17	41.98	25.57
Din-2	41.86	26.88
BC-2193	41.34	27.75

Source: Chowdhury *et al*., 2010; Sharif *et al*., 2017

Protein and oil content of different variety and advanced lines of BARI Sarisha are presented in Table 7. Highest amount of protein was obtained from BARI Sarisha-12 (29.69%), followed by BARI Sarisha-9 (29.25%). Lowest protein content was found in BARI Sarisha-14 (25.06%) which produced highest amount of oil (42.25%). For high oil content we can select BARI Sarisha-14 as one of the parents in breeding program.

Now in case of fatty acid composition Tale 8, highest amount of palmitic acid was observed in BARI Sarisha-17 (3.22%) and BARI Sarisha-12 (2.92%). Lowest amount of palmitic acid content was observed in advanced line Din-2 (0.627%).

Table 9. Fatty acid composition of different varieties and advanced lines of *Brassica*

Variety	Palmitic	Oleic	Erucic	Linoleic	Linolenic
BARI Sarisha-9	2.82	7.00	38.11	19.21	19.18
BARI Sarisha-12	2.92	14.28	50.50	17.42	9.32
BARI Sarisha-14	1.94	12.37	52.71	15.36	8.97
BARI Sarisha-15	2.22	15.40	48.70	16.06	9.15
BARI Sarisha-16	2.09	14.72	50.60	14.88	6.84
BARI Sarisha-17	3.22	18.69	51.35	14.38	5.84
Din-2	0.627	13.82	54.56	14.94	9.98
BC-2193	2.64	17.58	49.28	14.49	6.83

Source: Chowdhury *et al*., 2010

BARI Sarisha-17 (18.69%) contained highest amount of oleic acid and lowest amount was found in BARI Sarisha-9 (7.00%) among all the varieties. Lenoleic acid content of the varieties ranged from 14.38 to 19.21%. Highest amount of lenoleic acid content was found in BARI Sarisha-9 (19.21%) and lowest amount was found in BARI Sarisha-17 (14.38%). The linoleic acid content is important from the stand point of utilization of oil for food products. The concentration of linolenic acid varied from 5.84 to 19.18%. Differences were found among the varieties of mustard in respect of erucic acid content. Din-2 contained the highest amount of erucic acid (54.56%) followed by BARI Sarisha-14 (52.71%) and lowest amount was found in BARI Sarisha-9 (38.11%) among all the varieties.

3.6.2 Superior Cultivars Among Different *Brassica* species

In Bangladesh, mainly *B. campestris*, *B. napus* and *B. juncea* have been cultivated for centuries. However, the seed yield of the indigenous cultivar is very low (740 kg/ha) and only meets 30% of national needs (BBS, 2021). Recently several high yielding cultivars of mustard have developed. Those cultivars are varied from each other in their fatty acid compositions (Table 10, Table 11, Table 12).

Table 10. Fatty acid composition (% of total) of some cultivars of *Brassica campestris*

Cultivars	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Erucic
Tori-7	2.41	1.46	12.99	13.91	6.90	45.77
BINA Sarisha-6	1.81	1.51	12.27	12.98	6.33	49.98
Agrani	1.75	1.59	13.48	12.46	6.28	49.57
Safal	1.60	1.18	12.40	12.25	7.09	51.57
BARI Sarisha-6	1.70	1.47	13.93	11.79	6.29	50.33
BARI Sarisha-9	2.02	1.28	14.40	12.10	7.33	47.04
BARI Sarisha-12	1.20	1.05	13.06	12.63	8.02	48.62

Source: Mortuza *et al*., 2018

Among these seven varieties of *B. campestris*, Tori-7 contains lowest erucic acid (45.77%), highest linoleic acid (13.91) and moderate oleic (12.99%) and linolenic (6.90%). So this genotype may be exploited in future plant breeding programmes for development of nutritionally better quality locally adaptive cultivars.

Table 11. Fatty acid composition (% of total) of some cultivars of *Brassica napus*

Cultivars	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Erucic
BINA Sarisha- 3	3 3.15	1.22	19.09	14.12	10.37	32.88
BINA arisha-4	3.29	1.30	19.37	14.44	10.15	32.12
BINA Sarisha-5	3.52	1.50	32.23	13.97	7.68	21.59
BARI Sarisha-8	3.36	1.51	25.21	14.08	8.21	27.70
MM 2-16-98	3.18	1.22	16.35	14.05	10.48	36.21
MM 38-6-98	3.26	1.35	20.19	14.02	10.88	31.16
MM 49-3-98	3.01	1.23	17.31	15.27	11.13	32.95
MM 34-7-98	3.53	1.32	21.73	15.59	11.15	26.38

Source: Mortuza *et al*., 2018

Table 12. Fatty acid composition (% of total) of some *Brassica juncea* cultivars

Cultivars	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Erucic
MM 001/98	2.60	0.99	8.06	16.89	9.77	43.67
Jata	2.23	1.01	8.68	15.05	9.67	46.84
Barisarisha-10	2.26	1.08	7.03	15.29	10.54	47.39
Barisarisha-11	2.12	0.87	8.76	15.82	9.59	46.85
Rai-5	2.55	1.05	8.88	16.37	9.23	44.68

Source: Mortuza *et al*., 2018

Here the cultivars of *B. napus*, ie Binasarisha-3, Binasarisha-4, Binasarisha-5, Barisarisha-8 and some advanced lines such as MM 22-12-98, MM 2-16-98, MM 38- 6-98, MM 39-3-98 and MM 34-7-98 contained significantly larger amounts of palmitic acid (ranging from 3.01 to 3.53%) and the cultivars of *B. campestris*, ie Binasarisha-6, Agrani, Safal, Barisarisha-6 and Barisarisha-12, containe lower amounts of palmitic acid (1.20–1.60%) than Tori-7 (2.41%). A wide variation was observed in the oleic acid (18:1 n-9) content, ranging from 7.03 to 25.21%. Binasarisha-3, Binasarisha-4, Binasarisha-5, MM 22- 12-98, MM 2-16-98, MM 38-6-98, MM 39-3-98, MM 34-7-98 and Barisarisha-8 contained higher levels of oleic acid, ranging from 16.35 to 32.23%, than Tori-7 (12.99%). In contrast, a very low content of oleic acid was found in the cultivars/mutant lines of *B. juncea*, i,e MM 001/98, Jata, Rai-5, Barisarisha-10 and Barisarisha-11, which varied from 7.03 to 8.06%. The linoleic acid content ranged for 11.79–16.89%. Barisarisha-6 contained the smallest amount (11.79%), whereas MM 001/98 and Rai-5 contained the largest amount (ranging from 16.37 to 16.89%); all other cultivars contained more or less the same amount of linoleic acid.

The contents of erucic acid varied considerably ranging from 21.59 to 51.57%. Further genotypes, Binasarisha-3, Binasarisha-4, Binasarisha5, MM 22-12-98, MM 2-16-98, MM 36-6-98, MM 49-3-98, MM 34-7-98 and Barisarisha-8, of *B. napus* had low levels of erucic acid and high levels of oleic, linoleic and linolenic acids. These genotypes may be exploited in plant breeding programmes for development of nutritionally better quality locally adaptive cultivars.

3.6.3 Variation in Quality of Some Cultivars after Backcross

The considerable genetic variation and high heritability for different fatty acid composition suggested that selection for improving some of the fatty acid composition would be promising in the future breeding programme. Here, some superior cultivars of mustard were selected for backcross breeding to enhance the oil quality among them.

Table 13. Fatty acid composition of *Brassica campestris* after backcross breeding

Variety	**Population**	**Saturated**		**Unsaturated**			
		Palmatic	**Stearic**	**Oleic**	**Linoleic**	**Linolenic**	**Erucic**
Tori-7×BARI sarisha-15	P7	1.68	0.567	11.27	12.53	8.48	60.75
BARIsarisha-9× BARIsarisha-6 (S_5F_{12})	P9	1.83	0.49	14.77	12.83	8.38	54.79
SAUsarisha-1× BARI Sarisha-15 (F_7 Bulk)	P11	2.68	0.74	14.98	13.85	6.69	56.95
SAUsarisha-1× BARI Sarisha-15 (F_6)	P12	2.15	0.73	15.16	13.21	8.56	54.08
BARIsarisha-6× BARI sarisha-15 (F_9)	P13	1.84	0.67	13.63	14.27	8.65	55.16

Source: Karmokar, *et al.*, 2018

Here a bar diagram represent the relative value of different fatty acids content (%) among these five populations in Fig 2.

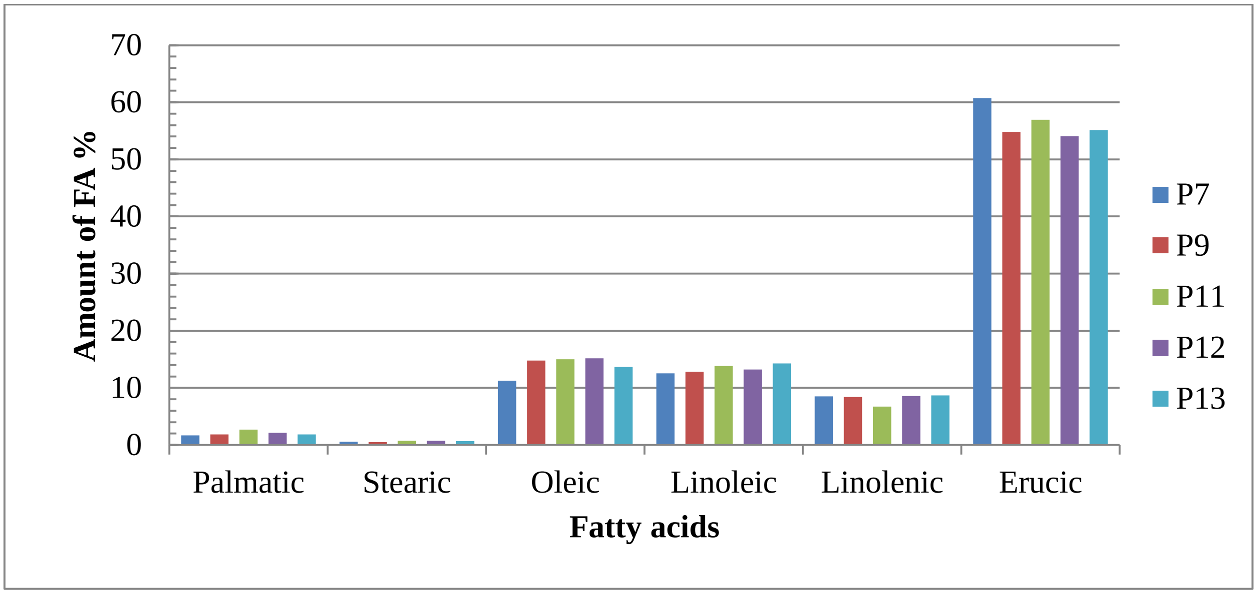

Figure 2. Fatty acid contents (%) of five populations (*Brassica campestris).*

Source: Karmokar, *et al*., 2018

Population P7 (11.27%) had the lowest amount of oleic acid content and followed by P13 (13.63%) and population P12 (15.16%) had the highest amount of oleic acid (Table 13). Minimum amount of erucic acid was found in P12 (54.08%) followed by P9 (54.79) and maximum found in P7 (60.75%) among five genotypes.

So, among the populations lowest amount of palmitic, stearic and erucic acid was found in P7 (Tori-7 x BARI sarisha-15 F6) (1.68%), P9 (BARI sarisha-9 X BARI sarisha-6 S5F15) (0.49%) and P12 (SAU sarisha-1 X BARI sarisha-15 F6) (54.08%) respectively. The highest amount of oleic, linoleic and linolenic acid was found in P12 (15.16%), P13 (BARI sarisha-6 X BARI sarisha-15 F9) (14.27%) and P13 (8.65%) respectively. Based on this information for saturated fatty acids populations P7 and P9 were good. For unsaturated fatty acids population P12 was better enough than other populations.

3.7 Problems in Quality Breeding

Most of the quality traits are polygenic in nature. Therefore, selection for quality traits during the segregating generations is very difficult. Moreover, quality traits are difficult to estimate and evaluate, therefore, quality breeding imposes considerable demand on resource, and time including money. Many quality traits have low heritability and are markedly affected by the environment. This retards the progress under selection.

3.8 Future Strategies for Quality Development

According to breeding purpose, designer crops might offer a solution because the quality requirements for consumption purposes differ from those for industrial or plant defense purposes. Designer crops with varying chemical composition such as low (> 3.5%) and high (>20%) linolenic acid; mid (65-75%) and high (>75%) oleic acid; high erucic acid-high glucosinolate; low erucic acid-high glucosinolate; high erucic acid-low glucosinolate; low erucic acid-low glucosinolate (double low quality, canola); and balanced ratios of SFA/MUFA/PUFA and omega6/omega3 etc. can be produced depending upon the purpose. Large-scale screening of the mustard germplasms preserved in the national gene bank is required for the creation of these designer crops in order to identify trait-specific germplasms and use them moving forward in crop improvement programs.

CHAPTER 4

CONCLUSION

Erucic acid in oil and glucosinolate in deoiled cake are two nutritionally toxic undesirable factors in mustard. Certain genotypes in the current study had very high erucic content, whereas others had very low erucic content. Several of the cultivars examined here offer desirable traits that could be exploited in upcoming breeding efforts for the development of nutritionally superior mustard cultivars. Oil and seed meal should be free or at non-toxic levels of anti-nutritional constituents including erucic acid <2% in edible oil and glucosinolate <30 µmol/g defatted seed meal. The selection for increasing some of the fatty acid composition in the future breeding program appeared promising given the significant genetic variation and high heritability for distinct fatty acid composition.

In the breeding point of view, genetic variety serves as the foundation upon which selection acts to create superior populations. The diversity of the populations that are available gives adequate opportunity to choose the top lines for upcoming trials. The populations among different cultivars such as Tori-7×BARI sarisha-15, BARIsarisha-9× BARIsarisha-6 and SAUsarisha-1× BARI Sarisha-15 can be used in future breeding program since they have low concentrations of erucic, palmitic, and stearic acid and high concentrations of oleic, linoleic, and linolenic acid. For high-quality mustard breeding, *B. napus*, which has low levels of erucic acid and high levels of oleic, linoleic, and linolenic acids, can be utilized as a future breeding tool for mustard.

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